IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of

Applicants: Bednorz et al.

Serial No.: 08/479,810

Filed: June 7, 1995

Appeal No. 2009-003320

Date: Dec. 18, 2009

Docket: YO987074BZ

Group Art Unit: 1751

Examiner: M. Kopec

For: NEW SUPERCONDUCTIVE COMPOUNDS HAVING HIGH TRANSITION TEMPERATURE, METHODS FOR THEIR USE AND PREPARATION

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SUPPLEMENT 2
REQUEST FOR REHEQRING
UNDER
37 C.F.R. § 41.52 (a)(1)
Of
Decision on Appeal dated 09/17/2009

ATTACHMENTS

Please charge any fee necessary to enter this paper and any previous paper to deposit account 09-0468.

Respectfully submitted,

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SERIES 4 KEYBOARDED C 45

O.-480
(EV. 5-67)

152254 /970

Serial No. (Series of 19)

MAY 29 1973 PATENT NUMBER   **3736048**

SERIAL NUMBER	FILING DATE	CLASS	SUBCLASS 186	GROUP ART UNIT	ASSISTANT EXAMINER
152,254	06/11/71	350	184	259	Corbin

APPLICANT(S) GORDON HENRY COOK, DACRY, ENGLAND, PETER ARNOLD MERIGOLD,
PRESTATYN, WALES

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② 47 Meadow Rd

BEST COPY

TITLE OF INVENTION OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH.

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ASSOCIATE ATTORNEY NONE

2 sh. dr. transferred from SN 309,208 3/29/2

☐ SUBSTITUTE FOR: FILED NONE ☐

SER. NO.	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEP. CLAIMS	FILING FEE RECEIVED	ATTORNEY'S DOCKET NO.	CLAIMS ALLOWED	CLASS	SUBCLASS
152,254	/80	3	27	2	$109	7955	22	350	186

CONTINUING DATA VERIFIED, EXAMINER'S INITIALS

THIS APPLICATION IS A C-I-P OF SN 305,208, 09/16/63.

CERTIFICATE
NOV 27 1973
OF CORRECTION

CLAIMS PRIORITY FOREIGN APPLICATION

MEETS CONDITIONS SPECIFIED IN 35 USC 119 YES ☒ NO ☐

Great Britain 35038 8/14/72

ASSIGNEE The Rank Organisation Limited, London, England.

U.S. DEPT. OF COMMERCE - PATENT OFFICE
FORM PO-436-L (8-70)

N.S.

PARTS OF APPLICATION FILED SEPARATELY

PREPARED FOR ISSUE

(Assistant Examiner)   (Docket Clerk)

EXAMINED FOR ISSUE
JCC EXAMINER
GROUP ART UNIT 259
(Primary Examiner Group) 259

Sheets-3 Fig-7

	PRINTED PAGES	ISSUE FEE DUE
Drw'g(s)	Spec(s)	
#6		$116

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Date mailed JAN 10 1973

Date paid 3-9-73 w.

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GROUP 250

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6-11-71 → Reel—2746
FRAME—550—②

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16-11878-10 U.S. GOVERNMENT PRINTING OFFICE

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Class	Sub	Date	Ex'r
350	184 186	5/72	JXC

INTERFERENCE SEARCHED

Class	Sub	Date	Ex'r
350	184 — 187	11/72	JXC

$$\frac{5}{72} \quad \frac{11}{72}$$

	claims 1. ✓	=
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CROSS REFERENCE(S)
(in numerical sequence)

		CLASS	SUBCLASS
SERIAL NUMBER	PATENT NUMBER	350	187
152,254		350	254

NAME

Gordon Henry Cook

SEARCH

CLASS	SUBCLASS
350	186

Class	Sub		CLASS	SUBCLASS
350	184	5,	350	186
	186			

INTERNATIONAL CLASSIFICATION

G02b 7/10
G02b 15/18

GROUP ART UNIT: 2 69

PLEASE PRINT FULL NAME
ASSISTANT EXAMINER

PRIMARY EXAMINER: John K. Corbin

FORM PO-270
(REV. 2-70)

ISSUE CLASSIFICATION SLIP

U.S. DEPARTMENT OF COMMERCE
PATENT OFFICE

5/12 11/72

	claims	
1	1. ✓	=
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	3. ✓	
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5	6. ✓	≡
6	7. ✓	
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9	11. ✓	=
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11	15. ✓	=
12	16. ✓	≡
13	17. ✓	=
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INTERFERENCE SEARCHED

Class	Sub	Date	Ex'r
350	184-187	11/72	JKC

[54] **OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH**

[75] Inventors: **Gordon Henry Cook**, Oadby, England; **Peter Arnold Merigold**, Prestatyn, Wales

[73] Assignee: **The Rank Organisation Limited**, London, England

[22] Filed: **June 11, 1971**

[21] Appl. No.: **152,254**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 309,208, Sept. 16, 1963, abandoned.

[52] **U.S. Cl.** 350/186, 350/187, 350/214
[51] **Int. Cl.** G02b 7/10, G02b 15/18
[58] **Field of Search** 350/184, 186

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Primary Examiner—John K. Corbin
Attorney—Holcombe, Wetherill & Brisebois

[57] **ABSTRACT**

A zoom lens having an improved zooming range and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_b lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_c lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_b$ and $2.5f_b$ and the total axial movement of the third member in the range lies numerically between $0.25f_c$ and $0.5f_c$, the minimum axial separation between the second and third members occurring when the equivalent focal length of the object is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between $0.5f_c$ and $1.0f_c$.

22 Claims, 7 Drawing Figures
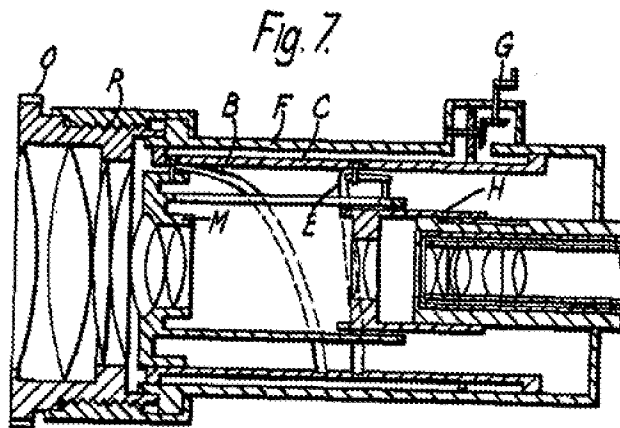
Fig.1

Fig.2

Fig.3
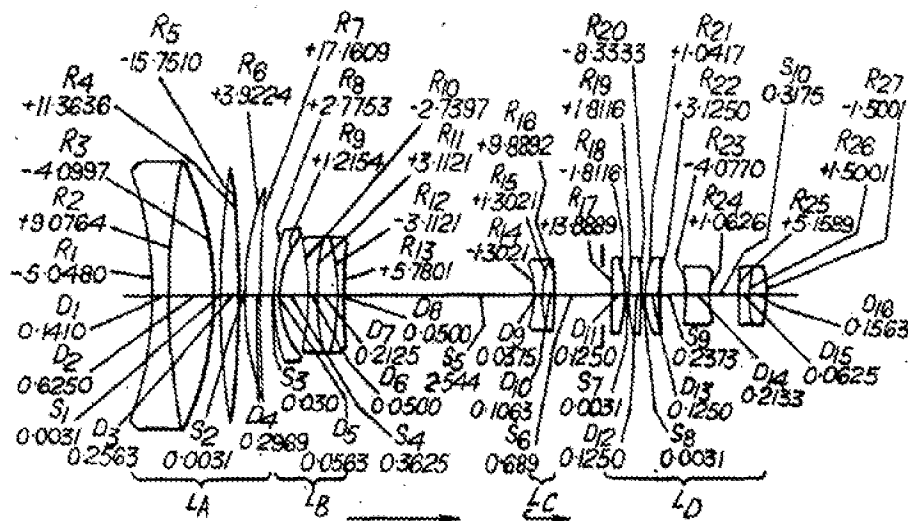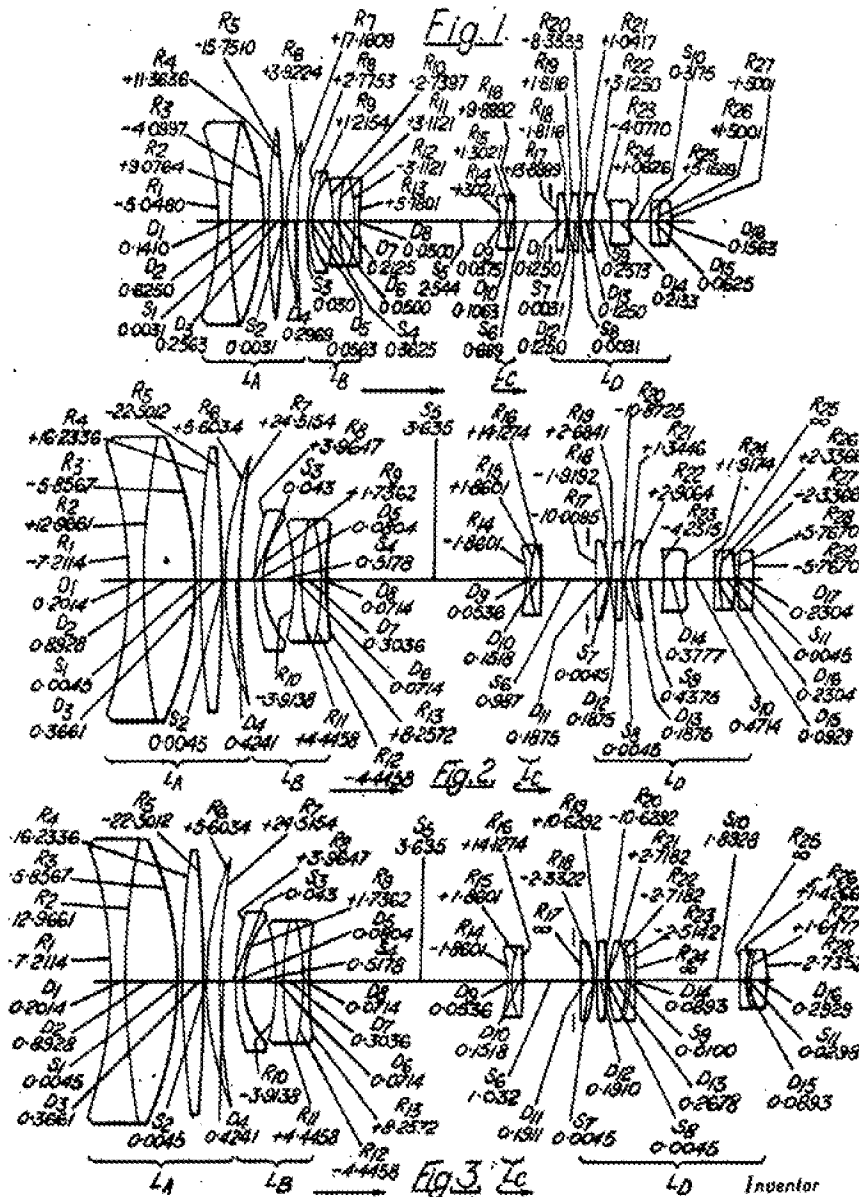
Inventor
P. A. Merigold
By G. H. Cook
Attorneys
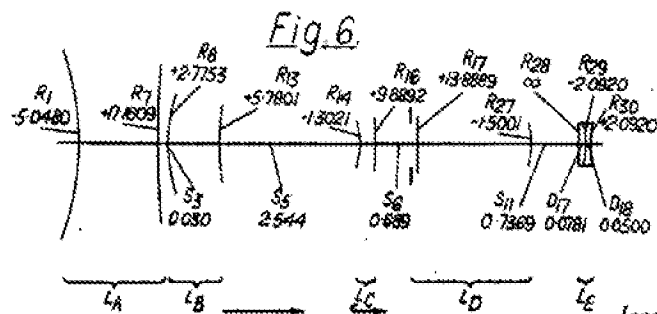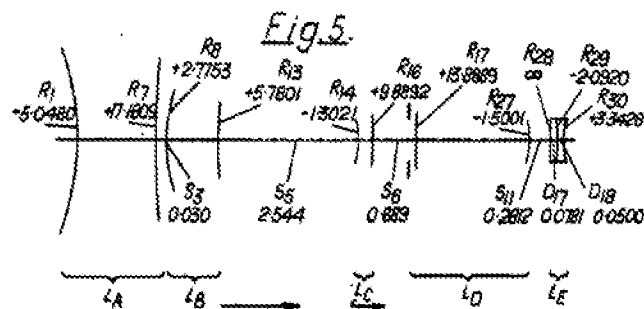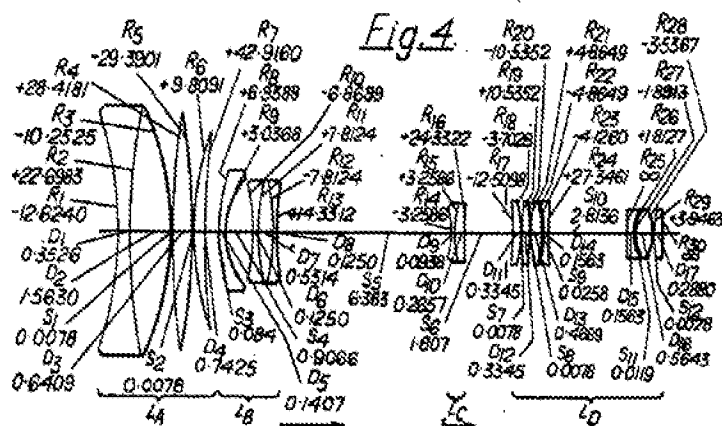
Fig. 4

Fig. 5

Fig. 6

Inventor
P. A. Merigold
G. H. Cook
By
Attorneys

Fig. 7

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OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

This application is a continuation-in-part of our prior application Ser. No. 309,208, filed Sept. 16, 1963, now abandoned.

This invention relates to an optical objective of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane, whereby the scale of the image can be varied, the objective being corrected for spherical and chromatic aberration, coma, astigmatism, field curvature and distortion. In this type of objective, accommodation for change of object position is usually achieved by imparting a movement, independent of the zooming relative movements, to the front member of the objective.

Many difficulties arise in the design of such objectives, and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this have usually involved the use of relatively complicated movable members in the objective in order to make it possible to stabilize the aberrations throughout the range of variation, such stabilized aberrations then being compensated in a stationary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the zoom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions or have introduced too severe optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the zooming movements for varying the equivalent focal length, so that this member is concerned only with focussing movements and is relieved of the complication of superimposing focussing movements on zooming movements. Such an arrangement is utilized in the present invention, wherein the primary object is to provide an improved arrangement of the movable zooming system of the objective, which can be employed with various different arrangements of the front member and will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

BRIEF SUMMARY OF THE INVENTION

The optical objective of the zoom type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative

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movements, the second and third are divergent and movable, and the fourth is convergent and stationary, the minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths f_B and f_C respectively of the movable second and third members lie numerically respectively between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective in the range of variation and between 5 and 10 times such minimum ratio, the divergent movable second member consisting of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent compound component and performing during the range of variation a total axial movement lying numerically between $1.5f_B$ and $2.5f_B$, whilst the divergent movable third member consists of a doublet component having a front surface concave to the front with radius of curvature lying numerically between $0.5f_C$ and $1.0f_C$ and performs during the range of variation a total axial movement lying numerically between $0.25f_C$ and $0.5f_C$.

Several specific examples of optical objectives as above described will be given later on in this specification, and a table will be found after the first example, together with an accompanying explanation showing the effect of varying those parameters for which ranges of variation are given in the preceding paragraph within the ranges specified in that paragraph.

It is to be understood that the terms "front" and "rear", as used herein, relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

In addition, the term "total axial movement" is used to refer to the total distance moved by a member during zooming from one end of the range to the other, independently of the direction of movement. Thus, a member may move forward and then back during the range of variation, and in this case the total axial movement is the numerical sum of the forward distance moved plus the rearward distance moved.

It should also be made clear that the term "internal contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the arithmetic mean between the radii of curvature of the individual contacting surfaces, whilst the optical power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall dimensions of the objective as small as possible and achieving the best compromise between the diameters and the relative apertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures

of the individual members, and at the same time to assist towards the desired stabilization of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

FURTHER FEATURES OF THE INVENTION

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbe V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilization of astigmatism and distortion, the radius of curvature of the front surface of the simple meniscus component of the second member preferably lies numerically between $1.5f_B$ and $3f_B$, and further assistance towards stabilization of astigmatism can be obtained by arranging for the radius of curvature of the rear surface of such component to lie numerically between $0.66f_B$ and $1.0B$. B.

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature lying numerically between $1.5f_B$ and $3f_B$, the rear surface of such component being convex to the front with radius of curvature lying numerically between $3f_B$ and $6f_B$, thus assisting towards stabilization of spherical aberration and coma.

Whilst such compound component may consist of a doublet component, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials for the various elements, facilitates correction of chromatic aberration and the desired stabilization of the other aberrations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one another by more than 0.15. The arithmetic mean between the Abbe V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5f_C$ and f_C, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25. These features contribute towards the desired stabilization of the spherical aberration and coma and also facilitate individual correction of the third member for chromatic aberration.

As in the case of the second member, it is preferable to employ materials for the elements of the third member having mean refractive indices greater than 1.65, in order to avoid excessive surface curvatures and thus

facilitate the attainment of a wide relative aperture for the member.

A movable system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially advantageous for such member to have one or more of the following characteristics:

A. The first member is preferably convergent and may comprise a front meniscus doublet component with its front and rear surfaces concave to the front followed by two simple convergent components, the front surface of the doublet component having dispersive optical power lying numerically between $0.5f_A$ and $1.0f_A$, where f_A is the equivalent focal length of the first member. These features permit the rear nodal point of the first member to be far to the rear and preferably behind the rear surface of the member, for cooperation with the forwardly located front nodal point of the second member.

B. The internal contact of the meniscus doublet component of the first member may be dispersive and convex to the front with radius of curvature between $1.5f_A$ and $3f_A$, the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15. These features contribute towards stabilization of spherical aberration and astigmatism over the desired focussing range to suit different object distances.

C. The two simple components of the first member may together have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4f_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than $0.75f_A$. These features assist towards stabilizing the aberrations, especially spherical aberration and astigmatism, not only throughout the range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D. The rear surface of the rear component of the first member may be convex to the front with radius of curvature between $2f_A$ and $7f_A$. This feature contributes towards stabilization of primary astigmatism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E. The axial thickness of the meniscus doublet component of the first member may be less than $0.25f_A$ and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than $0.075f_A$. These features contribute towards the desired rearward location of the rear nodal point of the first member.

F. The arithmetic mean between the Abbe V numbers of the material of the three convergent elements of the first member may exceed by at least 20 the Abbe V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G. The equivalent focal length f_A of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective. This feature as-

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sists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

H. If desired, an achromatic doublet component may be provided, which can be placed at will behind the rear member of the objective to increase the value of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the objective to be stationary and to be located behind the movable third member of the objective.

DESCRIPTION OF EMBODIMENTS

Some convenient practical examples of zoom objective according to the invention are illustrated diagrammatically in the accompanying drawings, in which

FIGS. 1 – 4 respectively illustrate four examples (FIG. 4 being on half the scale of FIGS. 1 – 3),

FIGS. 5 – 6 show the example of FIG. 1 (in skeleton form) modified by the addition respectively of two alternative constructions of achromatic doublet component detachably mounted behind the rear member of the objective, and

FIG. 7 is an axial section through a lens mount having suitable zoom control element for use in carrying out the invention.

Numerical data for these six examples are given in the following tables (numbered correspondingly to the figures of the drawings), in which R_1, R_2 . . . designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, D_1, D_2 . . . designate the axial thicknesses of the individual elements of the objective, and S_1, S_2 . . . designate the axial air separations between the components of the objective. The tables also give the mean refractive indices n_d for the d-line of the spectrum and the Abbe V numbers of the materials from which the various elements of the objective are made, and in addition the clear diameters of the various surfaces of the objective.

The second section of each table gives the values of the three variable axial air separations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value F_o to its maximum value F_n are also given, together with the corresponding values of log F.

Some of the tables also have a third section giving the equation defining an axial section through an aspheric surface provided in the stationary rear member of the objective, the radius of curvature given for such surface in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms of F_o.

The insertion of equals (=) signs in the radius columns of the tables, in company with plus (+) and minus (−) signs which indicate whether the surface is convex or concave to the front, is for conformity with the usual Patent Office custom, and it is to be understood that these signs are not to be interpreted wholly in their mathematical significance. This sign convention agrees with the mathematical sign convention required for the computation of some of the aberrations including the primary aberrations, but different mathematical sign

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conventions are required for other purposes including computation of some of the secondary aberrations, so that a radius indicated for example as positive in the tables may have to be treated as negative for some calculations as is well understood in the art.

EXAMPLE 1

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1 = -5.9180$	$D_1 = 0.1440$	1.7847	28.16	R_1 3.4435
$R_2 = +0.5764$	$D_2 = 0.8250$	1.51007	58.35	R_2 3.4700
$R_3 = -4.0987$	$S_1 = 0.0031$			R_3 3.4870
$R_4 = +11.3688$	$D_3 = 0.2568$	1.717	47.98	R_4 3.3716
$R_5 = -15.7518$	$S_2 = 0.0031$			R_5 3.3620
$R_6 = +8.9738$	$D_4 = 0.2069$	1.717	47.98	R_6 3.3035
$R_7 = +17.1800$	$S_3 = $ Variable			R_7 3.0707
$R_8 = +2.7703$	$D_5 = 0.0863$	1.80784	86.19	R_8 1.7000
$R_9 = +1.2354$	$S_4 = 0.3025$			R_9 1.4812
$R_{10} = -2.7397$	$D_6 = 0.0600$	1.60784	86.19	R_{10} 1.4713
$R_{11} = +5.1121$	$D_7 = 0.2125$	1.7847	28.16	R_{11} 1.4092
$R_{12} = -3.2131$	$D_8 = 0.0900$	1.89784	66.10	R_{12} 1.3947
$R_{13} = +5.7691$	$S_5 = $ Variable			R_{13} 1.3612
$R_{14} = -1.8031$	$D_9 = 0.0375$	1.69784	58.30	R_{14} 0.7803
$R_{15} = +1.8031$	$D_{10} = 0.1055$	1.7847	28.10	R_{15} 0.8205
$R_{16} = +0.8803$	$S_6 = $ Variable			R_{16} 0.8800
$R_{17} = +18.8880$	$D_{11} = 0.1200$	1.523	58.87	R_{17} 0.9085
$R_{18} = -1.8180$	$S_7 = 0.0031$			R_{18} 0.9017
$R_{19} = +1.8016$	$D_{12} = 0.1250$	1.523	58.87	R_{19} 0.9057
$R_{20} = -8.3333$	$S_8 = 0.0031$			R_{20} 0.9502
$R_{21} = +1.0417$	$D_{13} = 0.1280$	1.523	58.87	R_{21} 0.8358
$R_{22} = +3.1290$	$S_9 = 0.2273 *$			R_{22} 0.8502
$R_{23} = -4.0770$	$D_{14} = 0.3333$	1.7283	28.66	R_{23} 0.7580
$R_{24} = +5.0628$	$S_{10} = 0.3175$			R_{24} 0.8007
$R_{25} = +5.1655$	$D_{15} = 0.0825$	1.7283	28.98	R_{25} 0.7107
$R_{26} = +1.5001$	$D_{16} = 0.1585$	1.61452	58.23	R_{26} 0.7200
$R_{27} = -1.5001$				R_{27} 0.7225

* Aspheric.

S_3	S_5	S_6	F	log F
0.03023	2.54423	0.68858	1.00000	0.00
1.11409	1.40738	0.74157	1.77827	0.25
1.93439	0.60333	0.72521	3.16227	0.50
2.55076	0.16104	0.55123	5.62339	0.75
2.96231	0.36657	0.13414	10.00000	1.00

Equation for aspheric surface R_{19}

$$x = -4.077 + \sqrt{16.62193 - y^2} - 0.02459203\, y^4 + 0.08899172\, y^6$$
$$- 0.2440590\, y^8 - 0.07442450\, y^{10}$$

The foregoing Example describes a complete thick lens design, with values calculated in many cases to the fourth decimal place, and several additional Examples of this type will be given subsequently.

It is, however, obviously impractical to provide such fully calculated thick lens designs for values broadly distributed throughout the previously specified ranges for all the significant parameters.

However, in order to show the effect of altering the principal parameters within the ranges specified for those parameters, and demonstrate the practicality of designing lenses having parameter values near the ex-

tremes of the specified ranges, an illustrative table is given below. The parameters given are all thin lens parameters (parameters of the thin lens construction on which Example I is based) and the effects of these parameter variations are shown on the dimensions of the overall objective and the relative apertures (f-numbers) of the first three members.

In the following table:

F_B is the focal length of the second member;
F_C is the focal length of the third member;
T_B is the total axial movement of the second member;
T_C is the total axial movement of the third member;
R is the minimum value of the ratio of the focal length of the complete objective to its f-number;
L is the overall length from the front of the objective to the focal plane;
D is the maximum diameter at the front of the objective;
F_{N1} is the relative aperture of the first member;
F_{N2} is the relative aperture of the second member; and
F_{N3} is the relative aperture of the third member.

The four critical thin lens parameters set forth in the fifth paragraph of this specification and in the main claim are F_B, F_C, T_B, and T_C, and their values for Example I are shown in line 1 of the table. In line 2, F_B is put equal to the lower limit (4R) of the main claim, and in line 3 equal to the upper limit (8R). In lines 4 and 5 F_C is treated similarly. T_B and T_C are dealt with in similar manner in lines 6 and 7 and lines 8 and 9. It is not possible to vary the four parameters completely independently of one another (this is referred to again later), and in fact when one parameter is set to an end limit, at least two of the others have been adjusted, in the table, so that the range of variation of focal length remains approximately unchanged.

Line 3 shows the effect of putting F_B to its upper limit. Conversely, from the changes in L, D, F_{N1}, F_{N2} and F_{N3}, it can be seen that such a modified thin lens construction would be suitable for development of a final objective of relatively simple construction constructed to cover relatively large image format dimensions (at which scale high complexity would not be permissible) at a smaller relative aperture than Example I.

Lines 4 and 5 show identical effects achievable by putting F_C at its lower and upper limits.

Line 6 shows the effect of putting the total axial movement of the second member at its upper limit. In fact, in order to do this, it is necessary to put at least either F_B or F_C at or near its end limit. This is dictated by the fundamental laws of optics, also bearing in mind the requirement to keep the focal range roughly the same. However, the effect is now not quite the same as in lines 2 to 5, because one axial movement now also lies at its end limit. Thus, the change in L and D from Example I is reduced, while the relative aperture of one member (the third member) is increased but the other two are reduced. Lines 7 to 9 show similar effects; in extent from Example I, as also are F_{N1}, F_{N2} and F_{N3}. Reverting to line 6 in particular, this modification is suited to a moderately small but not extremely small dimensional scale of final objective having a medium relative aperture, wherein the smaller relative aperture of the third member either permits its complexity to be reduced or, more usefully, its existing complexity utilized to achieve an extremely high standard of aberration correction. Corresponding but slightly different effects can be seen from the modifications of lines 7 to 9.

In general therefore, it can readily be seen from the table how the parameters of the main claim can be taken to their end limits to provide differing effects suited to differing initial requirements. The lens de-

	F_B	F_C	T_B	T_C	L	D	F_{N1}	F_{N2}	F_{N3}
Example I	-1.42	-1.82	7.92	0.66	3.62	2.91	1.59	1.8	3.29
F_B=1.0 (4R)	-1.0	-1.82	2.74	6.59	2.93	2.56	1.54	0.02	2.16
F_B=2.0 (8R)	-2.0	-1.82	5.90	0.79	4.30	3.13	1.74	1.64	2.39
F_C=1.25 (5R)	-1.47	-1.25	2.44	6.58	3.11	3.61	1.40	1.00	1.67
F_C=2.5 (10R)	-1.47	-2.58	3.33	0.77	4.07	2.94	1.74	0.58	5.07
T_B2.5 (2.5F_B)	-1.0	-3.26	2.50	0.80	3.18	2.63	1.44	0.81	2.78
T_B3.0 (3.0F_B)	-2.0	-1.28	3.00	0.89	3.55	2.87	1.54	1.05	1.76
T_C0.58 (0.33F_C)	-1.8	-2.58	2.57	0.88	3.24	2.93	1.46	0.91	3.94
T_C0.72 (0.4F_C)	-2.0	-1.44	3.23	0.72	3.92	2.00	1.63	1.05	1.97

Example I is a zoom lens intended for construction to a medium dimensional scale to cover average format dimensions.

In line 2, the effect of putting F_B to its lower limit is to reduce L and D. F_{N1}, F_{N2} and F_{N3} are also reduced, meaning that each individual member has a wider relative aperture. Because of their wider relative apertures, these members would have to be more complex (contain more usable thick lens parameters) than they are in Example I, in order to achieve the same high standard of aberration correction. However, this greater complexity would be acceptable for a zoom objective built to a small dimensional scale covering small image format dimensions. Such a small scale construction would readily be possible in view of the reductions in L and D. Therefore, a zoom lens within the scope of the main claim, with F_B at or near its lower limit, would be preferred for a lens of wider relative aperture but constructed to a smaller dimensional scale than Example I.

signer given the main claim and having a particular end requirement can work accordingly.

The table also demonstrates the sense of the end limits. For example, to take F_B below the value of 1.0(4R) in line 2 would be further to decrease L and D and further widen the relative apertures of the second, third and fourth members. Obviously a question of opinion is involved at this point, but the opinion of the inventor is that the complexity of construction for the second to fourth members, in order to achieve good aberration correction at the further widened relative aperture, would render a practical construction a non-commercial proposition. Likewise to take F_B beyond the value of 2.0(8R) in line 3 would only permit construction of a practical corrected objective to such a large dimensional scale that it would find no useful application. The same factors also arise in the modifications of lines 6 to 9, when coupled with the requirement to maintain a large range of variation of focal length, which is an essential object of the invention.

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EXAMPLE II

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1 = -7.2114$				R_1 4.9192
	$D_1 = 0.2614$	1.7647	28.10	
$R_2 = +12.0561$				R_2 4.9542
	$D_2 = 0.8028$	1.51507	58.55	
$R_3 = -5.8587$				R_3 4.9814
	$S_1 = 0.0045$			
$R_4 = +16.2388$				R_4 4.8164
	$D_3 = 0.3691$	1.7170	47.90	
$R_5 = -23.5012$				R_5 4.8014
	$S_2 = 0.0045$			
$R_6 = +5.6034$				R_6 4.6885
	$D_4 = 0.4241$	1.7170	47.90	
$R_7 = +24.5154$				R_7 4.3867
	$S_3 = $ Variable			
$R_8 = +3.8947$				R_8 2.4286
	$D_5 = 0.6894$	1.69784	56.19	
$R_9 = +1.7362$				R_9 2.1161
	$S_4 = 0.5175$			
$R_{10} = -2.9188$				R_{10} 2.1013
	$D_6 = 0.0714$	1.69734	56.13	
$R_{11} = +4.4458$				R_{11} 2.0132
	$D_7 = 0.3030$	1.7647	28.10	
$R_{12} = -4.4458$				R_{12} 1.6325
	$D_8 = 0.0714$	1.69734	56.13	
$R_{13} = +8.2572$				R_{13} 1.6191
	$S_5 = $ Variable			
$R_{14} = -1.5851$				R_{14} 1.1159
	$D_9 = 0.0588$	1.69734	56.19	
$R_{15} = +1.5851$				R_{15} 1.1721
	$D_{10} = 0.1518$	1.7647	28.16	
$R_{16} = +14.1274$				R_{16} 1.1857
	$S_6 = $ Variable			
$R_{17} = -10.0005$				R_{17} 1.2553
	$D_{11} = 0.1875$	1.5168	64.20	
$R_{18} = -1.9192$				R_{18} 1.2861
	$S_7 = 0.0045$			
$R_{19} = +3.6841$				R_{19} 1.8110
	$D_{12} = 0.1875$	1.5168	64.20	
$R_{20} = -10.9725$				R_{20} 1.8023
	$S_8 = 0.0045$			
$R_{21} = +1.9446$				R_{21} 1.2873
	$D_{13} = 0.1875$	1.5168	64.20	
$R_{22} = -3.0094$				R_{22} 1.2226
	$R_{23} = 0.4875$*			
$R_{23} = -4.2315$				R_{23} 1.0808
	$D_{14} = 0.3777$	1.7285	28.66	
$R_{24} = +1.9374$				R_{24} 0.9955
	$R_{24} = 0.4734$			
$R_{25} = \infty$				R_{25} 1.0010
	$D_{15} = 0.0089$	1.7285	28.66	
$R_{26} = +2.3856$				R_{26} 1.0058
	$D_{16} = 0.2804$	1.61842	59.27	
$R_{27} = -2.3865$				R_{27} 1.0156
	$S_{10} = 0.0045$			
$R_{28} = +5.7873$				R_{28} 1.0058
	$D_{17} = 0.2804$	1.61842	59.27	
$R_{29} = -5.7873$				R_{29} 0.9778

*Aspheric.

S_2	S_3	S_5	F	log F
0.04318	3.63462	0.98730	1.00000	0.00
1.59156	2.01054	1.06300	1.77827	0.25
2.76329	0.86319	1.93962	3.16227	0.50
3.64395	0.23005	0.79109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

Equation for aspheric surface R_{23}

$$X = -4.2315 + \sqrt{17.90559 - y^2} - 0.01666805\, y^4 + 0.02010843\, y^6 - 0.00176346\, y^8 - 0.00553820\, y^{10}$$

EXAMPLE III

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1 = -7.2114$				R_1 4.9192
	$D_1 = 0.2614$	1.7647	28.10	
$R_2 = +17.0561$				R_2 4.9543
	$D_2 = 0.8028$	1.51507	58.55	
$R_3 = -5.8587$				R_3 4.9814
	$S_1 = 0.0045$			
$R_4 = +16.2388$				R_4 4.8164
	$D_3 = 0.3691$	1.7170	47.90	
$R_5 = -23.5012$				R_5 4.8014
	$S_2 = 0.0045$			
$R_6 = +5.6034$				R_6 4.4825
	$D_4 = 0.4241$	1.7170	47.90	
$R_7 = +24.5154$				R_7 4.3867
	$S_3 = $ variable			
$R_8 = +3.8947$				R_8 2.4286
	$D_5 = 0.6894$	1.69734	56.19	
$R_9 = +1.7362$				R_9 2.1161
	$S_4 = 0.5175$			
$R_{10} = -2.9188$				R_{10} 2.1013
	$D_6 = 0.0714$	1.69734	56.19	
$R_{11} = +4.4458$				R_{11} 2.0182
	$D_7 = 0.3088$	1.7647	28.10	

EXAMPLE IV (continued from Example II page)

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_{10} = -4.4458$				R_{11} 1.5935
	$D_{17} = 0.0714$	1.69734	56.13	
$R_{11} = +8.2572$				R_{12} 1.6161
	$S_7 = $ variable			
$R_{12} = -1.5851$				R_{13} 1.1168
	$D_{18} = 0.0588$	1.69734	56.18	
$R_{13} = +1.5851$				R_{14} 1.1721
	$D_{19} = 0.1518$	1.7647	28.16	
$R_{14} = +14.1274$				R_{15} 1.1857
	$S_8 = $ variable			
$R_{15} = \infty$				R_{16} 1.2530
	$D_{20} = 0.1311$	1.534	55.87	
$R_{16} = -2.3532$				R_{17} 1.3096
	$S_9 = 0.0045$			
$R_{17} = +10.5293$				R_{18} 1.5935
	$D_{21} = 0.1950$	1.534	55.87	
$R_{18} = -10.9292$				R_{19} 1.5936
	$S_{10} = 0.0045$			
$R_{19} = +2.7913$				R_{20} 1.3273
	$D_{22} = 0.2078$	1.61842	59.27	
$R_{20} = -2.7612$				R_{21} 1.3060
	$S_{11} = 0.0060$			
$R_{21} = -2.5143$				R_{22} 1.3048
	$D_{23} = 0.0932$	1.72580	28.86	
$R_{22} = \infty$				R_{23} 1.2934
	$S_{12} = 1.8028$			
$R_{23} = \infty$				R_{24} 0.8694
	$D_{24} = 0.0832$	1.72580	28.66	
$R_{24} = +1.4266$				R_{25} 0.9300
	$S_{13} = 0.0292$			
$R_{25} = +1.6477$				R_{26} 0.9300
	$D_{25} = 0.2929$	1.59784	58.19	
$R_{26} = -2.7352$				R_{27} 0.8300

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S_2	S_3	S_5	F	log F
0.04318	3.63462	1.0319	1.00000	0.00
1.59156	2.01054	1.1076	1.77827	0.25
2.76329	0.86219	1.08422	3.16227	0.50
3.64395	0.23005	0.83569	5.62339	0.75
4.23190	0.23796	0.23984	10.00000	1.00

EXAMPLE IV

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1 = -12.6245$				R_1 8.6135
	$D_1 = 0.2628$	1.7647	28.10	
$R_2 = +22.6653$				R_2 8.5900
	$D_2 = 1.2630$	1.51507	58.55	
$R_3 = -10.2525$				R_3 8.7208
	$S_1 = 0.0078$			
$R_4 = +35.4181$				R_4 8.4814
	$D_3 = 0.6409$	1.7173	47.93	
$R_5 = -30.5301$				R_5 8.4652
	$S_2 = 0.0078$			
$R_6 = +5.9891$				R_6 7.7612
	$D_4 = 0.7425$	1.7176	47.96	
$R_7 = +42.6195$				R_7 7.6782
	$S_3 = $ Variable			
$R_8 = +5.9588$				R_8 4.2516
	$D_5 = 0.1507$	1.60881	56.83	
$R_9 = +3.0568$				R_9 3.7045
	$E_1 = 0.9068$			
$R_{10} = -8.3899$				R_{10} 3.6185
	$D_6 = 0.1260$	1.60881	56.83	
$R_{11} = +7.8124$				R_{11} 3.5246
	$D_7 = 0.5314$	1.79503	20.09	
$R_{12} = -7.8124$				R_{12} 3.4676
	$D_8 = 0.1260$	1.60881	56.83	
$R_{13} = +34.3012$				R_{13} 3.3524
	$S_4 = $ Variable			
$R_{14} = -3.2588$				R_{14} 1.9329
	$D_9 = 0.0034$	1.60881	56.83	
$R_{15} = +8.2588$				R_{15} 2.0236
	$D_{10} = 0.3857$	1.79503	25.00	
$R_{16} = +26.3923$				R_{16} 2.0774
	$S_5 = $ Variable			
$R_{17} = -13.5908$				R_{17} 2.3574
	$D_{11} = 0.3342$	1.65031	58.60	
$R_{18} = -3.7028$				R_{18} 2.3860
	$S_6 = 0.0078$			
$R_{19} = +10.5852$				R_{19} 2.5312
	$D_{12} = 0.3342$	1.65031	58.60	
$R_{20} = -10.5852$				R_{20} 2.5312
	$S_7 = 0.0078$			
$R_{21} = +4.8640$				R_{21} 2.2337
	$D_{13} = 0.4689$	1.51817	60.27	
$R_{22} = -4.8640$				R_{22} 2.2280
	$S_8 = 0.0098$			
$R_{23} = -4.1266$				R_{23} 2.2245
	$D_{14} = 0.1582$	1.7282	28.06	
$R_{24} = +27.3461$				R_{24} 2.1562
	$S_9 = 2.8126$			
$R_{25} = \infty$				R_{25} 1.7174
	$D_{15} = 0.1582$	1.76198	26.18	
$R_{26} = +1.8127$				R_{26} 1.7380
	$S_{10} = 0.0139$			
$R_{27} = +1.6913$				R_{27} 1.7382
	$D_{16} = 0.5849$	1.55031	58.60	
$R_{28} = -5.5857$				R_{28} 1.7741
	$S_{11} = 0.0078$ *			
$R_{29} = +5.5482$				R_{29} 1.7554
	$D_{17} = 0.2890$	1.65031	58.60	
$R_{30} = \infty$				R_{30} 1.7150

* Aspheric.

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S_3	S_4	S_5	F	log F
0.08428	6.36327	1.80704	1.00000	0.0
2.79513	3.51989	1.93956	1.77827	0.25
4.84654	1.50941	1.89864	3.16227	0.5
6.38837	0.40269	1.46352	5.62339	0.75
7.41774	0.41652	0.42013	10.00000	1.0

Equation for aspheric surface R_{10}

$$x = +\,3.9463 - \sqrt{15.57328 - y^2} + 0.00427020\, y^4 - 0.00777096\, y^6 + 0.00721693\, y^{10}$$

In all these examples, the maximum value F_α of the equivalent focal length F of the objective is ten times the minimum value F_ω thereof. Example I is corrected for a relative aperture $f/4.0$, whilst Examples II and III are each corrected for a relative aperture $f/2.8$, and Example IV is corrected for a relative aperture of $f/1.6$. Examples II and III differ from one another solely in the stationary rear member L_D, the front three members L_A, L_B and L_C being identical in the two examples. Such members L_A, L_B and L_C are in fact similar to the front three members L_A, L_B and L_C of Example I, the dimensions being scaled up from those of Example I in the ratio of the f-numbers, that is in the ratio of 4.0/2.8. The rear members L_D in Examples II and III are, however, not scaled-up versions of the rear member L_D of Example I. The front three members L_A, L_B, L_C of Example IV, which includes yet another alternative construction of rear member L_D, are of the same general type as those of Examples I-III, but their numerical dimensions differ somewhat from a version of those of Example I scaled up in the ratio 4.0/1.6.

All these examples cover a semi-angular field of view varying from 27 degrees at F_α to 2.7 degrees at F_ω.

The iris diaphragm in all four examples is stationary and is located between the movable third member L_C and the stationary rear member L_D. In Example I the diaphragm is 0.0625 F_α in front of the surface R_{12} and has diameter 0.8568 F_α; in Example II the diaphragm is 0.0929 F_α in front of the surface R_{13} and has diameter 1.2240 F_α; in Example III the diaphragm is 0.1375 F_α in front of the surface R_{13} and has diameter 1.2240 F_α; and in Example IV the diaphragm is 0.2407 F_α in front of the surface R_{11} and has diameter 2.1446 F_α.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F_α in Example I, 2.6761 F_α in Example II, 2.3027 F_α in Example III and 1.7878 F_α in Example IV.

The equivalent focal length f_A of the stationary first member L_A is + 4.4551 F_α in Example I, + 6.3644 F_α in Examples II and III and + 11.1415 F_α in Example IV; the equivalent focal length f_B of the movable second member L_B is − 1.4703 F_α in Example I, − 2.1004 F_α in Examples II and III and − 3.6770 F_α in Example IV; the equivalent focal length f_C of the movable third member L_C is − 1.8176 F_α in Example I, − 2.5966 F_α in Examples II and III and − 4.5458 F_α in Example IV; and the equivalent focal length f_D of the stationary fourth member L_D is + 1.4753 F_α in Example I, + 2.1286 F_α in Example II, + 2.3232 F_α in Example III and + 4.0419 F_α in Example IV; the positive and negative signs respectively indicating convergence and divergence.

In all four examples, the convergent stationary front member L_A consists of a meniscus doublet component followed by two convergent simple components. The front surface R_1 of the doublet component is concave to the front and has dispersive optical power numerically equal to 0.155/F_α or 0.692/f_A in Example I, to 0.109/F_α or 0.692/f_A in Examples II and III, and to 0.062/F_α or 0.692/f_A in Example IV. The internal contact R_2 of the doublet component is dispersive and convex to the front and has radius of curvature equal to 2.037 f_A in all four examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is 0.27 in all four examples.

The combined equivalent focal length of the two simple components of the first member L_A is 4.0013 F_α in Example I, 5.7162 F_α in Examples II and III, and 10.0064 F_α in Example IV or 0.8981 f_A in all four examples. The radius of curvature R_4 of the front surface of the first of such simple components is 2.551 f_A in all four examples, and the radius of curvature R_6 of the front surface of the second of such simple components is 0.880 f_A in all four examples. The rear surface R_7 of such second simple component is convex to the front with radius of curvature 3.852 f_A in all four examples.

The axial thickness $(D_1 + D_2)$ of the meniscus doublet component of the first member L_A is 0.766 F_α in Example I, 1.094 F_α in Examples II and III, and 1.916 F_α in Example IV, or 0.172 f_A in all four examples. The sum of the axial thicknesses of the two simple components $(D_3 + D_4)$ of the first member is 0.553 F_α in Example I, 0.790 F_α in Examples II and III, and 1.383 F_α in Example IV, or 0.124 f_A in all four examples.

The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member L_A in all four examples is 50.72 and thus exceeds the Abbe V number of the material of the divergent front element by 24.62.

The maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective is 2.5 F_α in Example I, 3.57 F_α in Examples II and III, and 6.25 F_α in Example IV, so that in all four examples f_A is 1.782 times such maximum value.

In all four examples, the minimum separation between the movable second and third members L_B and L_C occurs when the equivalent focal length of the objective is 7.45 F_α, and the numerical values of the equivalent focal lengths f_B and f_C of such members are respectively 5.88 and 7.27 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective.

The movable second member L_B in all four examples consists of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent element between two divergent elements, and its total axial movement (a unidirectional rearward movement) in the range of variation is numerically equal to 1.994 f_K. The front and rear surfaces R_8 and R_9 of the simple meniscus component of such member respectively have radii of curvature numerically equal to 1.89 f_B and 0.83 f_B in all four examples, whilst the front and rear surfaces R_{10} and R_{13} of the triplet component respectively have radii of curvature numerically equal to 1.86 f_B in Examples I − III and 1.87 f_B in Example IV and to 3.93 f_B in Examples I−III and 3.99 f_B in Example IV.

The movable third member L_C in all four examples consists of a doublet component, whose front surface R_{14} is concave to the front with radius of curvature numerically equal to 0.72 f_C, and the total axial movement (the numerical sum of an initial forward movement

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plus a subsequent rearward movement) of such member is numerically equal to 0.363 f_C. The internal contact R_{16} of such doublet component is collective and convex to the front, with radius of curvature numerically equal to 0.72 f_C. The difference between the mean refractive indices of the materials of such doublet component is 0.087 in Examples I – III and 0.088 in Example IV, the difference between their Abbe V numbers being 30.09 in Examples I – III and 30.24 in Example IV.

In all four examples, the various aberrations are well stabilized in the front three members L_A, L_B, L_C throughout the range of variation of equivalent focal length of the objective and also throughout the focussing range, and the stationary rear member L_D serves to balance out such residual stabilized aberrations, and also to locate the resultant image plane in a convenient position. The construction of such rear member may thus vary widely.

In Examples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilized aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R_{26} of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and coma with minimum effect on oblique aberrations.

In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no aspheric surface is used in the actual example given, some further improvement in aberration correction could be achieved by incorporating such a surface.

Yet another alternative construction for the stationary rear member L_D is employed in Example IV, consisting of seven simple components, the first three and the last two being convergent, and the fourth and fifth divergent. An aspheric surface is again used, in this case the front surface R_{29} of the rearmost component.

It is often desired in practice to provide two different ranges of variation of the equivalent focal length of the objective, and with the objective according to the present invention this can be carried out in a simple way by the provision of an achromatic doublet component, which can be placed at will behind the stationary rear member L_D of the objective, such doublet component, when in position, acting to move the resultant image plane further from the rear surface of the member L_D and to increase the values of the equivalent focal length of the objective in the same proportion throughout the range. Another effect of the addition of this doublet component is to reduce the relative aperture of the objective and the angular field covered. Numerical data

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are given below of two alternative examples of achromatic doublet component suited to follow the rear member L_D of Example I above. FIGS. 5 and 6 respectively show these two examples of doublet component L_E in position behind the main objective, which for simplicity is shown only in skeleton form, the front and rear surfaces only being shown for each of the four members L_A, L_B, L_C and L_D of the objective.

EXAMPLE V

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_{30} = \infty$	$S_{11} = 0.2812$			R_{30} 0.7312
$R_{31} = -2.0923$	$D_{17} = 0.0781$	1.70085	30.28	R_{31} 0.7312
$R_{32} = +3.8426$	$D_{18} = 0.0500$	1.60868	43.83	R_{32} 0.7312

EXAMPLE VI

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_{30} = \infty$	$S_{11} = 0.7589$			R_{30} 0.6749
$R_{31} = -2.0520$	$D_{17} = 0.0781$	1.70085	30.73	R_{31} 0.6749
$R_{32} = +2.0520$	$D_{18} = 0.0500$	1.60982	52.31	R_{32} 0.6749

The dimensions in these two examples of achromatic doublet component are given in terms of the minimum value F_o of the equivalent focal length for the objective of Example I. In each table S_{11} represents the air separation between the rear surface R_{29} of the stationary rear member L_D of Example I and the front surface R_{30} of the added doublet component. The doublet component in each case consists of a convergent element in front of a divergent element.

The added doublet component L_E of Example V increases the values of the equivalent focal length in the ratio 3:2, so that the normal range from F_o to 10 F_o is altered by the doublet component into a range from 1.5 F_o to 15 F_o. The doublet component of Example VI acts to double the values of the equivalent focal length of Example I, thus giving a range from 2 F_o to 20 F_o when the doublet component is in position.

The back focal distance from the rear surface R_{32} of the added doublet component L_E to the new position of the resultant image plane is 3.704 F_o in Example V and 4.028 F_o in Example VI. The relative aperture of the objective is changed from $f/4.0$ by the addition of the doublet component to $f/6.0$ in Example V and $f/8.0$ in Example VI. The semi-angular field, which for Example I alone varies from 27 degrees at F_o to 2.7 degrees at F_m, varies (when the doublet component of Example V is added) from 18 degrees at 1.5 F_o to 1.8 degrees at 15 F_o, and (when the doublet component of Example VI is added) from 13.5 degrees at 2 F_o to 1.35 degrees at 20 F_m.

It will be realized that the addition of only an achromatic doublet component to an already well-corrected objective must necessarily result in a lower standard of aberration correction when the doublet component is in place. But the increased equivalent focal length and reduced relative aperture and angular field do not call for so high a standard of correction as is needed when the objective is used alone, and for many practical purposes the standard of correction obtained with the dou-

blet component added is adequate.

The necessary axial movement of the second and third members may be brought about in various ways, for example by means of two appropriately shaped cams, which may be in the form of cam grooves B and E on the inner surface of a tubular member C rotated by the zoom control element G and surrounding the second and third members M and H, which are held against rotation relatively to the fixed casing F of the objective. The focussing movement of the front member P may be effected under the control of a focussing control element O by mounting the front member in screw threaded engagement with the fixed casing F of the objective.

It will be appreciated that the foregoing examples have been given by way of example only and that the invention can be carried into practice in other ways.

We claim

1. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane), corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, said objective having a maximum equivalent focal length at least 6 times its minimum focal length, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_B lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_C lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_B$ and $2.5f_B$ and the total axial movement of the third member in the range lies numerically between $0.25f_C$ and $0.5f_C$, the minimum axial separation between the second and third member occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front.

2. An optical objective as claimed in claim 1, in which the compound component in the divergent movable second member includes at least one convergent element and at least one divergent element made of materials of differing Abbe V numbers.

3. An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front.

4. An optical objective as claimed in claim 3, in

which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

5. An optical objective as claimed in claim 4, in which the doublet component constituting the third member has a collective internal contact convex to the front.

6. An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front.

7. An optical objective as claimed in claim 2, in which the doublet component constituting the third member has a collective internal contact convex to the front, and the materials of the two elements of such component having differing Abbe V numbers and differing mean refractive indices.

8. An optical objective as claimed in claim 1, in which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front.

9. An optical objective as claimed in claim 8, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements, the materials of all the elements of the second member having mean refractive indices greater than 1.69 and being such that the arithmetic mean between the Abbe V numbers of the materials of the divergent elements exceeds that of the convergent element.

10. An optical objective as claimed in claim 9, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

11. An optical objective as claimed in claim 1, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

12. An optical objective as claimed in claim 11, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature substantially equal to $0.72f_C$, the materials of the two elements of such component having Abbe V numbers which differ by about 30 and mean refractive indices which are each greater than 1.69 and differ by about 0.09.

13. An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature substantially equal to $0.72f_C$, the difference between the mean refractive indices of the materials of the two elements of such component being about 0.09, while the difference between the Abbe V numbers of such materials is about 30.

14. An optical objective as claimed in claim 13, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

15. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining

constant position of the image plane), corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_b lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_c lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5 f_b$ and $2.5 f_b$ and the total axial movement of the third member in the range lies numerically between $0.25 f_c$ and $0.5 f_c$, the minimum axial separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, the movable divergent third member consisting of a doublet component having its front surface concave to the front, and the first member of the objective comprises a meniscus doublet component having a front surface which is concave to the front and two simple convergent components behind such meniscus doublet component.

16. An optical objective as claimed in claim 15, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front.

17. An optical objective as claimed in claim 16, in which the compound component in the divergent movable second member includes at least one convergent element and at least one divergent element, and the doublet component constituting the third member has a collective internal contact convex to the front.

18. An optical objective as claimed in claim 15, in which the two simple components of the first member together have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being greater than twice the radius of curvature of the front surface of the second of such simple components, the rear surface of the second of the two simple components being convex to the front.

19. An optical objective as claimed in claim 15, in which the axial thickness of the meniscus doublet component of the first member is greater than the sum of the axial thicknesses of the two simple components of the first member.

20. An optical objective as claimed in claim 19, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

21. An optical objective as claimed in claim 15, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

22. An optical objective as claimed in claim 21, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front with radius of curvature substantially equal to $2.04 f_b$, the difference between the mean refractive indices of the materials of the two elements of the doublet being substantially 0.27.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,736,048   Dated   May 29, 1973

Inventor(s) GORDON HENRY COOK and PETER ARNOLD MERIGOLD

It is certified that error appears in the above-identified patent
and that said Letters Patent are hereby corrected as shown below:

[73] Assignee: The Rank Organisation Limited
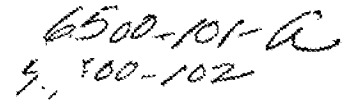   London, England

[30]   Foreign Application Priority Data
       Sept. 14, 1962   Great Britain.........35088

       Signed and sealed this 27th day of November 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.   RENE D. TEGTMEYER
Attesting Officer   Acting Commissioner of Patents

6500-101-a
5,700-102

152254

TO ALL WHOM IT MAY CONCERN:

Be it known that we, Gordon Henry Cook and Peter Arnold
Merigold, Subjects of the Queen of England, and residents
of Oadby, County of Leicester, England, and Prestatyn,
County of Flintshire, Wales, United Kingdom respectively,
have invented certain new and useful improvements in
Optical Objectives of Variable Equivalent Focal Length,
of which the following is a specification:-

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OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

ABSTRACT OF THE DISCLOSURE

A zoom lens having an improved zooming range
and comprising a convergent first member which for a
given object distance remains stationary during the
zooming relative movements, an axially movable divergent
second member behind the first member having equivalent
focal length f_B lying numerically between 4 and 8 times
the minimum value of the ratio of the equivalent focal
length of the complete objective to the f-number of the
objective in the range of variation, an axially movable
divergent third member behind the second member having
equivalent focal length f_C lying numerically between 5
and 10 times the minimum value of such ratio, a
stationary convergent fourth member behind the third
member, a zoom control element, and means whereby
operation of the zoom control element causes the zooming
relative movements to be effected, wherein the total
axial movement of the second member in the range of
variation lies numerically between $1.5f_B$ and $2.5f_B$ and
the total axial movement of the third member in the
range lies numerically between $0.25f_C$ and $0.5f_C$, the
minimum axial separation between the second and third
members occurring when the equivalent focal length of
the objective is greater than half its maximum value in
the range of variation, the movable divergent second
member consisting of a divergent simple meniscus
component with its surfaces convex to the front and a
divergent compound component behind such simple component,

and the movable divergent third member consisting of
a doublet component having its front surface concave to
the front with radius of curvature lying numerically
between $0.5f_0$ and $1.0f_0$.

BACKGROUND TO THE INVENTION

This application is a continuation-in-part
of our prior application Serial No. 309,208, filed
September 16, 1963, now abandoned .

This invention relates to an optical objective
of the "zoom" type, that is of the type having relatively
movable members whereby under the control of a zoom
control element the equivalent focal length of the
objective can be continuously varied throughout a range,
whilst maintaining constant position of the image plane,
whereby the scale of the image can be varied, the
objective being corrected for spherical and chromatic
aberration, coma, astigmatism, field curvature and
distortion.   In this type of objective, accommodation
for change of object position is usually achieved by
imparting a movement, independent of the zooming relative
movements, to the front member of the objective.

Many difficulties arise in the design of such
objectives, and one of the problems facing designers of
today is to achieve an increased range of variation of
equivalent focal length and, where possible, also an
increased angular field of view.   Attempts to achieve
this have usually involved the use of relatively
complicated movable members in the objective in order
to make it possible to stabilise the aberrations
throughout the range of variation, such stabilised

aberrations then being compensated in a stationary
rear member of the objective which also serves to
locate the resultant image plane in a convenient
position.   This in turn involves the use of relatively
large and heavy movable members and not only increases
the bulk and size of the complete objective, but also
presents severe mechanical problems in controlling the
movements, especially bearing in mind that at least one
of the movable members must necessarily perform a
movement bearing a non-linear relationship to the
movement of the zoom control element.   Many attempts
to extend the range of variation of the equivalent
focal length have failed, because they have demanded
departures from linearity of movement which are
impracticable mechanically, and often too because they
have involved an increase in the bulk and size of the
objective to unmanageable proportions or have introduced
too severe optical difficulties in achieving aberration
correction.

One way of reducing the mechanical complexities
is so to arrange the system that the front member does
not participate in the zooming movements for varying
the equivalent focal length, so that this member is
concerned only with focussing movements and is relieved
of the complication of superimposing focussing movements
on zooming movements.   Such an arrangement is utilised
in the present invention, wherein the primary object is
to provide an improved arrangement of the movable zooming
system of the objective, which can be employed with
various different arrangements of the front member and

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will cooperate therewith to enable aberration stability
to be achieved throughout a widely extended range of
variation of the equivalent focal length of the objective.

BRIEF SUMMARY OF THE INVENTION

The optical objective of the zoom type according
to the present invention has four members of which the
first (counting from the front) for a given object
distance remains stationary during the zooming relative
movements, the second and third are divergent and
movable, and the fourth is convergent and stationary,
the minimum separation between the second and third
members occurring when the equivalent focal length of
the objective is greater than half its maximum value in
the range of variation, whilst the equivalent focal
lengths f_B and f_C respectively of the movable second
and third members lie numerically respectively between
4 and 8 times the minimum value of the ratio of the
equivalent focal length of the objective to the f-number
of the objective in the range of variation and between
5 and 10 times such minimum ratio, the divergent movable
second member consisting of a divergent simple meniscus
component with its surfaces convex to the front followed
by a divergent compound component and performing during
the range of variation a total axial movement lying
numerically between $1.5f_B$ and $2.5f_B$, whilst the
divergent movable third member consists of a doublet
component having a front surface concave to the front
with radius of curvature lying numerically between $0.5f_C$
and $1.0f_C$ and performs during the range of variation a
total axial movement lying numerically between $0.25f_C$

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and $0.5f_o$.

Several specific examples of optical objectives
as above described will be given later on in this
specification, and a table will be found after the

5 first example, together with an accompanying
explanation showing the effect of varying those
parameters for which ranges of variation are given in
the preceding paragraph within the ranges specified in
that paragraph.

10 It is to be understood that the terms "front"
and "rear", as used herein, relate respectively to the
sides of the objective nearer to and further from the
longer conjugate in accordance with the usual convention.

In addition, the term "total axial movement"

15 is used to refer to the total distance moved by a member
during zooming from one end of the range to the other,
independently of the direction of movement.   Thus, a
member may move forward and then back during the range
of variation, and in this case the total axial movement

20 is the numerical sum of the forward distance moved plus
the rearward distance moved.

It should also be made clear that the term
"internal contact", when used in connection with a
compound component, is intended to include, not only a

25 cemented contact, but also what is commonly known as a
"broken contact", that is one in which the two contacting
surfaces have slightly different radii of curvature, the
effective radius of curvature of such a broken contact
being the arithmetic mean between the radii of curvature

30 of the individual contacting surfaces, whilst the optical

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power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall dimensions of the objective as small as possible and achieving the best compromise between the diameters and the relative apertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures of the individual members, and at the same time to assist towards the desired stabilization of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

FURTHER FEATURES OF THE INVENTION

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbe V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilisation of astigmatism and distortion, the radius of curvature of

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the front surface of the simple meniscus component of
the second member preferably lies numerically between
$1.5f_B$ and $3f_B$, and further assistance towards
stabilisation of astigmatism can be obtained by
arranging for the radius of curvature of the rear
surface of such component to lie numerically between
$0.66f_B$ and $1.0f_B$.

The front surface of the compound component of
the second member is preferably concave to the front
with radius of curvature lying numerically between $1.5f_B$
and $3f_B$, the rear surface of such component being convex
to the front with radius of curvature lying numerically
between $3f_B$ and $6f_B$, thus assisting towards stabilisation
of spherical aberration and coma.

Whilst such compound component may consist of
a doublet component, it will usually be preferable for
it to be in the form of a triplet component having a
convergent element between two divergent elements.
This, in view of the limited availability of suitable
materials for the various elements, facilitates
correction of chromatic aberration and the desired
stabilisation of the other aberrations without excessive
curvature of the individual surfaces.

The avoidance of excessive surface curvatures
can also be assisted by employing for all the elements
of the second member materials whose mean refractive
indices are greater than 1.65, whilst the mean refractive
indices of the materials of the elements of the compound
component in such member do not differ from one another
by more than 0.15. The arithmetic mean between the

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Abbe V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5f_c$ and f_c, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25. These features contribute towards the desired stabilisation of spherical aberration and coma and also facilitate individual correction of the third member for chromatic aberration.

As in the case of the second member, it is preferable to employ materials for the elements of the third member having mean refractive indices greater than 1.65, in order to avoid excessive surface curvatures and thus facilitate the attainment of a wide relative aperture for the member.

A movable system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially advantageous for such member to have one or more of the following characteristics:-

A) The first member is preferably convergent and

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may comprise a front meniscus doublet component with
its front and rear surfaces concave to the front followed
by two simple convergent components, the front surface of
the doublet component having dispersive optical power
lying numerically between $0.5/f_A$ and $1.0/f_A$, where f_A
is the equivalent focal length of the first member.
These features permit the rear nodal point of the first
member to be far to the rear and preferably behind the
rear surface of the member, for cooperation with the
forwardly located front nodal point of the second member.

B)   The internal contact of the meniscus doublet
component of the first member may be dispersive and
convex to the front with radius of curvature between
$1.5f_A$ and $3f_A$, the difference between the mean refractive
indices of the materials of the two elements of such
doublet component being greater than 0.15.   These
features contribute towards stabilisation of spherical
aberration and astigmatism over the desired focussing
range to suit different object distances.

C)   The two simple components of the first member
may together have a combined equivalent focal length
between $0.75f_A$ and $1.25f_A$, their front surfaces each
being convex to the front, the radius of curvature of
the front surface of the first of such simple components
being less than $4f_A$ and greater than twice the radius
of curvature of the front surface of the second of such
simple components, which latter radius of curvature may
in turn be greater than $0.75f_A$.   These features assist
towards stabilising the aberrations, especially spherical
aberration and astigmatism, not only throughout the

range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D)   The rear surface of the rear component of the first member may be convex to the front with radius of curvature between $2f_A$ and $7f_A$.   This feature contributes towards stabilization of primary astigmatism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E)   The axial thickness of the meniscus doublet component of the first member may be less than $0.25f_A$ and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than $0.075f_A$.   These features contribute towards the desired rearward location of the rear nodal point of the first member.

F)   The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member may exceed by at least 20 the Abbe V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G)   The equivalent focal length f_A of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective.   This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

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B)(i)   If desired, an achromatic doublet component may be provided, which can be placed at will behind the rear member of the objective to increase the value of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the objective to be stationary and to be located behind the movable third member of the objective.

DESCRIPTION OF EMBODIMENTS

Some convenient practical examples of zoom objective according to the invention are illustrated diagrammatically in the accompanying drawings, in which

(Figures 1 + 4 respectively illustrate four examples (Figure 4 being on half the scale of Figures 1 + 3),

Figures 5 + 6 show the example of Figure 1 (in skeleton form) modified by the addition respectively of two alternative constructions of achromatic doublet component detachably mounted behind the rear member of the objective, and

Figure 7 is an axial section through a lens mount having suitable zoom control element for use in carrying out the invention.

Numerical data for these six examples are given in the following tables (numbered correspondingly to the figures of the drawings), in which R_1, R_2 .... designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and

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the negative sign that it is concave thereto, D_1, D_2 ....
designate the axial thicknesses of the individual
elements of the objective, and S_1, S_2 .... designate the
axial air separations between the components of the
objective. The tables also give the mean refractive
indices n_d for the d-line of the spectrum and the
Abbe V numbers of the materials from which the various
elements of the objective are made, and in addition the
clear diameters of the various surfaces of the objective.

The second section of each table gives the
values of the three variable axial air separations between
the four members of the objective for a number of
representative positions, for which the corresponding
values of the equivalent focal length F of the complete
objective from its minimum value F_c to its maximum value
F_m are also given, together with the corresponding
values of log F.

Some of the tables also have a third section
giving the equation defining an axial section through
an aspheric surface provided in the stationary rear
member of the objective, the radius of curvature given
for such surface in the first section of the table being
the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms
of F_c.

The insertion of equals (=) signs in the radius
columns of the tables, in company with plus (+) and
minus (-) signs which indicate whether the surface is
convex or concave to the front, is for conformity with
the usual Patent Office custom, and it is to be understood

that these signs are not to be interpreted wholly in
their mathematical significance.   This sign convention
agrees with the mathematical sign convention required
for the computation of some of the aberrations including

5   the primary aberrations, but different mathematical sign
conventions are required for other purposes including
computation of some of the secondary aberrations, so
that a radius indicated for example as positive in the
tables may have to be treated as negative for some

10   calculations as is well understood in the art.

Example I

Radius		Thickness or Air Separation		Refractive Index n_d	Abbe V Number	Clear Diameter	
R_1	= − 5.0480					R_1	3.4435
		D_1	= 0.1410	1.7847	26.10		
R_2	= + 9.0764					R_2	3.4750
		D_2	= 0.6250	1.51507	56.35		
R_3	= − 4.0997					R_3	3.4870
		S_1	= 0.0031				
R_4	= + 11.3636					R_4	3.3715
		D_3	= 0.2563	1.717	47.90		
R_5	= − 15.7510					R_5	3.3610
		S_2	= 0.0031				
R_6	= + 3.9224					R_6	3.1035
		D_4	= 0.2969	1.717	47.90		
R_7	= + 17.1609					R_7	3.0707
		S_3	= variable				
R_8	= + 2.7753					R_8	1.7000
		D_5	= 0.0563	1.69734	56.19		
R_9	= + 1.2154					R_9	1.4812
		S_4	= 0.3625				
R_{10}	= − 2.7397					R_{10}	1.4712
		D_6	= 0.0500	1.69734	56.19		
R_{11}	= + 3.1121					R_{11}	1.4092
		D_7	= 0.2125	1.7847	26.10		
R_{12}	= − 3.1121					R_{12}	1.3947
		D_8	= 0.0500	1.69734	56.19		
R_{13}	= + 5.7801					R_{13}	1.3412
		S_5	= variable				
R_{14}	= − 1.3021					R_{14}	0.7807
		D_9	= 0.0375	1.69734	56.19		
R_{15}	= + 1.3021					R_{15}	0.8205
		D_{10}	= 0.1063	1.7847	26.10		
R_{16}	= + 9.8892					R_{16}	0.8300
		S_6	= variable				
R_{17}	= + 13.8889					R_{17}	0.8865
		D_{11}	= 0.1250	1.524	58.87		
R_{18}	= − 1.8116					R_{18}	0.9017
		S_7	= 0.0031				
R_{19}	= + 1.8116					R_{19}	0.9157
		D_{12}	= 0.1250	1.524	58.87		
R_{20}	= − 8.3333					R_{20}	0.9102
		S_8	= 0.0031				
R_{21}	= + 1.0417					R_{21}	0.8858
		D_{13}	= 0.1250	1.524	58.87		
R_{22}	= + 3.1250					R_{22}	0.8602
		S_9	= 0.2373 (aspheric)				
R_{23}	= − 4.0770					R_{23}	0.7560
		D_{14}	= 0.2133	1.7283	28.66		
R_{24}	= + 1.0626					R_{24}	0.6907
		S_{10}	= 0.3175				
R_{25}	= + 5.1589					R_{25}	0.7197
		D_{15}	= 0.0625	1.7283	28.66		
R_{26}	= + 1.5001					R_{26}	0.7200
		D_{16}	= 0.1563	1.61452	56.22		
R_{27}	= − 1.5001					R_{27}	0.7225

s_3	s_5	s_6	F	log F
0.03023	2.54423	0.68858	1.00000	0.00
1.11409	1.40738	0.74157	1.77827	0.25
1.93430	0.60333	0.72521	3.16227	0.50
2.55076	0.16104	0.55123	5.62339	0.75
2.96233	0.16657	0.13414	10.00000	1.00

Equation for aspheric surface R_{23}

$$x = -4.077 + \sqrt{16.62193 - x^2} - 0.02459203\, y^4 + 0.08899172\, y^6$$
$$- 0.2440590\, y^8 - 0.07442450\, y^{10}$$

The foregoing Example describes a complete thick lens design, with values calculated in many cases to the fourth decimal place, and several additional Examples of this type will be given subsequently.

It is, however, obviously impractical to provide such fully calculated thick lens designs for values broadly distributed throughout the previously specified ranges for all the significant parameters.

However, in order to show the effect of altering the principal parameters within the ranges specified for those parameters, and demonstrate the practicality of designing lenses having parameter values near the extremes of the specified ranges, an illustrative table is given below. The parameters given are all thin lens parameters (parameters of the thin lens construction on which Example I is based) and the effects of these parameter variations

are shown on the dimensions of the overall objective and the relative apertures (f-numbers) of the first three members.

In the following table:

F_B is the focal length of the second member;

F_C is the focal length of the third member;

T_B is the total axial movement of the second member;

T_C is the total axial movement of the third member;

R is the minimum value of the ratio of the focal length of the complete objective to its f-number;

L is the overall length from the front of the objective to the focal plane;

D is the maximum diameter at the front of the objective;

F_{N1} is the relative aperture of the first member;

F_{N2} is the relative aperture of the second member; and

F_{N3} is the relative aperture of the third member.

The four critical thin lens parameters set forth in the fifth paragraph of this specification and in the main claim are F_B, F_C, T_B, and T_C, and their values for Example I are shown in line 1 of the table. In line 2, F_B is put equal to the lower limit (4R) of the main claim, and in line 3 equal to the upper limit (8R). In lines 4 and 5 F_C is treated similarly. T_B and T_C are dealt with in similar manner in lines 6 and 7 and lines 8 and 9. It is not possible to vary the four parameters completely independently of one another (this is referred to again later), and in fact when one parameter is set to an end limit, at least two of the others have been adjusted, in the table, so that the range of variation of

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		F_B	F_C	T_B	T_C	L	D	F_{N1}	F_{N2}	F_{N3}
1	Example 1	-1.47	-1.82	2.93	0.66	3.62	2.81	1.59	1.0	2.29
2	F_B-1.0 (4R)	-1.0	-1.82	2.24	0.56	2.90	2.56	1.34	0.92	2.19
3	F_B-2.0 (8R)	-2.0	-1.82	3.60	0.79	4.30	3.12	1.74	1.04	2.39
4	F_C-1.25 (5R)	-1.47	-1.25	2.44	0.58	3.11	2.69	1.40	1.00	1.67
5	F_C-2.5 (10R)	-1.47	-2.50	3.38	0.77	4.07	2.94	1.74	0.98	3.07
6	T_B2.5 (2.5F_B)	-1.0	-2.36	2.50	0.66	3.18	2.62	1.44	0.91	2.78
7	T_B3.0 (1.5F_B)	-2.0	-1.26	3.00	0.69	3.68	2.87	1.54	1.06	1.76
8	T_C0.68 (0.27F_C)	-1.0	-2.50	2.57	0.68	3.24	2.69	1.46	0.91	2.94
9	T_C0.72 (0.5F_C)	-2.0	-1.44	3.22	0.72	3.91	3.00	1.63	1.05	1.97

Example I is a zoom lens intended for construction to a medium dimensional scale to cover average format dimensions.

In line 2, the effect of putting F_B to its lower limit is to <u>reduce</u> L and D. F_{N1}, F_{N2} and F_{N3} are also <u>reduced</u>, meaning that each individual member has a <u>wider</u> relative aperture. Because of their wider relative apertures, these members would have to be more complex (contain more usable thick lens parameters) than they are in Example I, in order to achieve the same high standard of aberration correction. However, this greater complexity would be acceptable for a zoom objective built to a small dimensional scale covering small image format dimensions. Such a small scale construction would readily be possible in view of the reductions in L and D. Therefore, a zoom lens within the scope of the main claim, with F_B at or near its lower limit, would be preferred for a lens of wider relative aperture

but constructed to a smaller dimensional scale than
Example I.

Line 3 shows the effect of putting F_B to its
upper limit.   Conversely, from the changes in L, D, F_{N1},
F_{N2} and F_{N3}, it can be seen that such a modified thin
lens construction would be suitable for development of a
final objective of relatively simple construction
constructed to cover relatively large image format
dimensions (at which scale high complexity would not
be permissible) at a smaller relative aperture than
Example I.

Lines 4 and 5 show identical effects achievable
by putting F_C at its lower and upper limits.

Line 6 shows the effect of putting the total
axial movement of the second member at its upper limit.
In fact, in order to do this, it is necessary to put at
least either F_B or F_C at or near its end limit.   This is
dictated by the fundamental laws of optics, also bearing
in mind the requirement to keep the focal range roughly
the same.   However, the effect is now not quite the
same as in lines 2 to 5, because one axial movement now
also lies at its end limit.   Thus, the change in L and
D from Example I is reduced, while the relative aperture
of one member (the third member) is increased but the
other two are reduced.   Lines 7 to 9 show similar
effects;   in extent from Example I, as also are F_{N1},
F_{N2} and F_{N3}.   Reverting to line 6 in particular, this
modification is suited to a moderately small but not
extremely small dimensional scale of final objective
having a medium relative aperture, wherein the smaller

relative aperture of the third member either permits
its complexity to be reduced or, more usefully, its
existing complexity utilised to achieve an extremely
high standard of aberration correction. Corresponding
but slightly different effects can be seen from the
modifications of lines 7 to 9.

In general therefore, it can readily be seen
from the table how the parameters of the main claim can
be taken to their end limits to provide differing effects
suited to differing initial requirements. The lens
designer given the main claim and having a particular
end requirement can work accordingly.

The table also demonstrates the sense of the
end limits. For example, to take F_B below the value of
1.0(4R) in line 2 would be further to decrease L and D
and further widen the relative apertures of the second,
third and fourth members. Obviously a question of
opinion is involved at this point, but the opinion of
the inventor is that the complexity of construction for
the second to fourth members, in order to achieve good
aberration correction at the further widened relative
aperture, would render a practical construction a non-
commercial proposition. Likewise to take F_B beyond the
value of 2.0(8R) in line 3 would only permit construction
of a practical corrected objective to such a large
dimensional scale that it would find no useful application.
The same factors also arise in the modifications of lines
6 to 9, when coupled with the requirement to maintain a
large range of variation of focal length, which is an
essential object of the invention.

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Example II

Radius		Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter	
R_1	= - 7.2114				R_1	4.9192
		D_1 = 0.2014	1.7847	26.10		
R_2	= + 12.9661				R_2	4.9642
		D_2 = 0.8928	1.51507	56.35		
R_3	= - 5.8567				R_3	4.9814
		S_1 = 0.0045				
R_4	= + 16.2336				R_4	4.8164
		D_3 = 0.3661	1.7170	47.90		
R_5	= - 22.5012				R_5	4.8014
		S_2 = 0.0045				
R_6	= + 5.6034				R_6	4.4335
		D_4 = 0.4241	1.7170	47.90		
R_7	= + 24.5154				R_7	4.3867
		S_3 = variable				
R_8	= + 3.9647				R_8	2.4286
		D_5 = 0.0804	1.69734	56.19		
R_9	= + 1.7362				R_9	2.1161
		S_4 = 0.5178				
R_{10}	= - 3.9138				R_{10}	2.1018
		D_6 = 0.0714	1.69734	56.19		
R_{11}	= + 4.4458				R_{11}	2.0132
		D_7 = 0.3036	1.7847	26.10		
R_{12}	= - 4.4458				R_{12}	1.9925
		D_8 = 0.0714	1.69734	56.19		
R_{13}	= + 8.2572				R_{13}	1.9161
		S_5 = variable				
R_{14}	= - 1.8601				R_{14}	1.1153
		D_9 = 0.0536	1.69734	56.19		
R_{15}	= + 1.8601				R_{15}	1.1721
		D_{10} = 0.1518	1.7847	26.10		
R_{16}	= + 14.1274				R_{16}	1.1857
		S_6 = variable				
R_{17}	= - 10.0095				R_{17}	1.2552
		D_{11} = 0.1875	1.5168	64.20		
R_{18}	= - 1.9192				R_{18}	1.2861
		S_7 = 0.0045				
R_{19}	= + 2.6841				R_{19}	1.3110
		D_{12} = 0.1875	1.5168	64.20		
R_{20}	= - 10.8725				R_{20}	1.3033
		S_8 = 0.0045				
R_{21}	= + 1.3446				R_{21}	1.2672
		D_{13} = 0.1875	1.5168	64.20		
R_{22}	= + 2.9064				R_{22}	1.2220
		S_9 = 0.4375 (aspheric)				
R_{23}	= - 4.2315				R_{23}	1.0500
		D_{14} = 0.3777	1.7283	28.66		
R_{24}	= + 1.9174				R_{24}	0.9686
		S_{10} = 0.4714				
R_{25}	= ∞				S_{25}	1.0019
		D_{15} = 0.0929	1.7283	28.66		
R_{26}	= + 2.3366				R_{26}	1.0088
		D_{16} = 0.2304	1.61342	59.27		
R_{27}	= - 2.3366				R_{27}	1.0186
		S_{11} = 0.0045				
R_{28}	= + 5.7670				R_{28}	1.0068
		D_{17} = 0.2304	1.61342	59.27		
R_{29}	= - 5.7670				R_{29}	0.9778

S_3	S_5	S_6	F	$\log F$
0.04318	3.63462	0.98730	1.00000	0.00
1.59156	2.01054	1.06300	1.77827	0.25
2.76329	0.86219	1.03962	3.16227	0.50
3.64395	0.23005	0.79109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

Equation for aspheric surface R_{23}

$$x = -4.2315 + \sqrt{17.90559 - y^2} - 0.01666805\, y^4 + 0.02010843\, y^6$$
$$- 0.00176346\, y^8 - 0.00553820\, y^{10}$$

Example III

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter
$R_1 = -\ 7.2114$				$R_1 \quad 4.9192$
	$D_1 = 0.2014$	1.7847	26.10	
$R_2 = +\ 12.9661$				$R_2 \quad 4.9642$
	$D_2 = 0.8928$	1.51507	56.35	
$R_3 = -\ 5.8567$				$R_3 \quad 4.9814$
	$S_1 = 0.0045$			
$R_4 = +\ 15.2336$				$R_4 \quad 4.8164$
	$D_3 = 0.3661$	1.7170	47.90	
$R_5 = -\ 22.5012$				$R_5 \quad 4.8014$
	$S_2 = 0.0045$			
$R_6 = +\ 5.6034$				$R_6 \quad 4.4335$
	$D_4 = 0.4241$	1.7170	47.90	
$R_7 = +\ 24.5154$				$R_7 \quad 4.3867$
	$S_3 = $ variable			
$R_8 = +\ 3.5647$				$R_8 \quad 2.4286$
	$D_5 = 0.0804$	1.69734	56.19	
$R_9 = +\ 1.7362$				$R_9 \quad 2.1161$
	$S_4 = 0.5178$			
$R_{10} = -\ 3.9318$				$R_{10} \quad 2.1018$
	$D_6 = 0.0714$	1.69734	56.19	
$R_{11} = +\ 4.4458$				$R_{11} \quad 2.0132$
	$D_7 = 0.3036$	1.7847	26.10	
$R_{12} = -\ 4.4458$				$R_{12} \quad 1.9925$
	$D_8 = 0.0714$	1.69734	56.19	
$R_{13} = +\ 6.2572$				$R_{13} \quad 1.9161$
	$S_5 = $ variable			
$R_{14} = -\ 1.8601$				$R_{14} \quad 1.1153$
	$D_9 = 0.0536$	1.69734	56.19	
$R_{15} = +\ 1.8601$				$R_{15} \quad 1.1721$
	$D_{10} = 0.1518$	1.7847	26.10	
$R_{16} = +\ 14.1274$				$R_{16} \quad 1.1857$
	$S_6 = $ variable			
$R_{17} = \quad \infty$				$R_{17} \quad 1.2830$
	$D_{11} = 0.1911$	1.524	58.87	
$R_{18} = -\ 2.3322$				$R_{18} \quad 1.3098$
	$S_7 = 0.0045$			
$R_{19} = +\ 10.6292$				$R_{19} \quad 1.3238$
	$D_{12} = 0.1910$	1.524	58.87	
$R_{20} = -\ 10.6292$				$R_{20} \quad 1.3288$
	$S_8 = 0.0045$			
$R_{21} = +\ 2.7812$				$R_{21} \quad 1.3273$
	$D_{13} = 0.2678$	1.61342	59.27	
$R_{22} = -\ 2.7812$				$R_{22} \quad 1.3060$
	$S_9 = 0.0100$			
$R_{23} = -\ 2.5142$				$R_{23} \quad 1.3049$
	$D_{14} = 0.0893$	1.72830	28.66	
$R_{24} = \quad \infty$				$R_{24} \quad 1.2833$
	$S_{10} = 1.8928$			
$R_{25} = \quad \infty$				$R_{25} \quad 0.9600$
	$D_{15} = 0.0893$	1.72830	28.66	
$R_{26} = +\ 1.4266$				$R_{26} \quad 0.9600$
	$S_{11} = 0.0298$			
$R_{27} = +\ 1.6477$				$R_{27} \quad 0.9600$
	$D_{16} = 0.2929$	1.69734	56.19	
$R_{28} = -\ 2.7352$				$R_{28} \quad 0.9600$

TA $\quad s_3 \quad$ TD $\quad s_5 \quad$ TE $\quad s_6 \quad$ TF $\quad$ F $\quad$ TG log F

B {

s_3	s_5	s_6	F	log F
0.04318	3.63462	1.0319	1.00000	0.00
1.59156	2.01054	1.1076	1.77827	0.25
2.76329	0.86219	1.08422	3.16227	0.50
3.64395	0.23005	0.83569	5.62339	0.75
4.23190	0.23796	0.23984	10.00000	1.00

PS

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Example IV

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter
$R_1 = -12.6240$				R_1 8.6115
	$D_1 = 0.3526$	1.7847	26.10	
$R_2 = +22.6983$				R_2 8.6903
	$D_2 = 1.5630$	1.51507	56.35	
$R_3 = -10.2525$				R_3 8.7203
	$S_1 = 0.0078$			
$R_4 = +28.4181$				R_4 8.4314
	$D_3 = 0.6409$	1.7170	47.90	
$R_5 = -29.3901$				R_5 8.4052
	$S_2 = 0.0078$			
$R_6 = +9.8091$				R_6 7.7612
	$D_4 = 0.7425$	1.7170	47.90	
$R_7 = +42.9160$				R_7 7.6792
	$S_3 = $ variable			
$R_8 = +6.9388$				R_8 4.2516
	$D_5 = 0.1407$	1.69681	56.33	
$R_9 = +3.0368$				R_9 3.7045
	$S_4 = 0.9066$			
$R_{10} = -6.8699$				R_{10} 3.6795
	$D_6 = 0.1250$	1.69681	56.33	
$R_{11} = +7.8124$				R_{11} 3.5240
	$D_7 = 0.5314$	1.78503	26.09	
$R_{12} = -7.8124$				R_{12} 3.4870
	$D_8 = 0.1250$	1.69681	56.33	
$R_{13} = +14.3312$				R_{13} 3.3528
	$S_5 = $ variable			
$R_{14} = -3.2586$				R_{14} 1.9539
	$D_9 = 0.0938$	1.69681	56.33	
$R_{15} = +3.2586$				R_{15} 2.0536
	$D_{10} = 0.2657$	1.78503	26.09	
$R_{16} = +24.3322$				R_{16} 2.0774
	$S_6 = $ variable			
$R_{17} = -12.5098$				R_{17} 2.2274
	$D_{11} = 0.3345$	1.65031	58.60	
$R_{18} = -3.7028$				R_{18} 2.2899
	$S_7 = 0.0078$			
$R_{19} = +10.5352$				R_{19} 2.3212
	$D_{12} = 0.3345$	1.65031	58.60	
$R_{20} = -10.5352$				R_{20} 2.3181
	$S_8 = 0.0078$			
$R_{21} = +4.8649$				R_{21} 2.2837
	$D_{13} = 0.4689$	1.61317	59.27	
$R_{22} = -4.8649$				R_{22} 2.2259
	$S_9 = 0.0258$			
$R_{23} = -4.1260$				R_{23} 2.2243
	$D_{14} = 0.1563$	1.7282	28.66	
$R_{24} = +27.3461$				R_{24} 2.1602
	$S_{10} = 2.8136$			
$R_{25} = \infty$				R_{25} 1.7178
	$D_{15} = 0.1563$	1.76128	26.98	
$R_{26} = +1.8127$				R_{26} 1.7350
	$S_{11} = 0.0119$			
$R_{27} = +1.8913$				R_{27} 1.7382
	$D_{16} = 0.5643$	1.65031	58.60	
$R_{28} = -3.5367$				R_{28} 1.7741
	$S_{12} = 0.0078$ (aspheric)			
$R_{29} = +3.9463$				R_{29} 1.7554
	$D_{17} = 0.2880$	1.65031	58.60	
$R_{30} = \infty$				R_{30} 1.7100

S_3	S_5	S_6	F	log F
0.08428	5.36327	1.80704	1.00000	0.0
2.79513	3.51989	1.93956	1.77827	0.25
4.84654	1.50941	1.89864	3.16227	0.5
6.38837	0.40269	1.46352	5.62339	0.75
7.41774	0.41652	0.42032	10.00000	1.0

Equation for aspheric surface R_{29}

$$x = +3.9463 - \sqrt{15.57328 - y^2} + 0.00427020\, y^6 - 0.0077096\, y^8 + 0.0072169\bar{3}\, y^{10}$$

In all these examples, the maximum value F_m of the equivalent focal length F of the objective is ten times the minimum value F_0 thereof. Example I is corrected for a relative aperture f/4.0, whilst Examples II and III are each corrected for a relative aperture f/2.8, and Example IV is corrected for a relative aperture of f/1.6. Examples II and III differ from one another solely in the stationary rear member L_D, the front three members L_A, L_B and L_C being identical in the two examples. Such members L_A, L_B and L_C are in fact similar to the front three members L_A, L_B and L_C of Example I, the dimensions being scaled up from those of Example I in the ratio of the f-numbers, that is in the ratio of 4.0/2.8. The rear members L_D in Examples II and III are, however, not scaled-up versions of the rear member L_D of Example I. The front three members L_A, L_B, L_C of Example IV, which includes yet another alternative

construction of rear member L_D, are of the same general type as those of Examples I = III, but their numerical dimensions differ somewhat from a version of those of Example I scaled up in the ratio 4.0/1.6.

All these examples cover a semi-angular field of view varying from 27 degrees at F_O to 2.7 degrees at F_m.

The iris diaphragm in all four examples is stationary and is located between the movable third member L_C and the stationary rear member L_D. In Example I the diaphragm is 0.0625 F_O in front of the surface R_{17} and has diameter 0.8568 F_O; in Example II the diaphragm is 0.0929 F_O in front of the surface R_{17} and has diameter 1.2240 F_O; in Example III the diaphragm is 0.1375 F_O in front of the surface R_{17} and has diameter 1.2240 F_O; and in Example IV the diaphragm is 0.2407 F_O in front of the surface R_{17} and has diameter 2.1446 F_O.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F_O in Example I, 2.6761 F_O in Example II, 2.3027 F_O in Example III and 1.7878 F_O in Example IV.

The equivalent focal length f_A of the stationary first member L_A is + 4.4551 F_O in Example I, + 6.3644 F_O in Examples II and III and + 11.1415 F_O in Example IV; the equivalent focal length f_B of the movable second member L_B is - 1.4703 F_O in Example I, - 2.1004 F_O in Examples II and III and - 3.6770 F_O in Example IV; the equivalent focal length f_C of the movable third member L_C is - 1.8176 F_O in Example I, - 2.5966 F_O in Examples II and III and - 4.5458 F_O in Example IV; and the equivalent

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focal length f_D of the stationary fourth member L_D is
+ 1.4753 F_0 in Example I, + 2.1286 F_0 in Example II,
+ 2.3232 F_0 in Example III and + 4.0419 F_0 in Example IV;
the positive and negative signs respectively indicating
convergence and divergence.

In all four examples, the convergent stationary
front member L_A consists of a meniscus doublet component
followed by two convergent simple components. The front
surface R_1 of the doublet component is concave to the
front and has dispersive optical power numerically equal
to 0.155/F_0 or 0.692/f_A in Example I, to 0.109/F_0 or
0.692/f_A in Examples II and III, and to 0.062/F_0 or
0.692/f_A in Example IV. The internal contact R_2 of the
doublet component is dispersive and convex to the front
and has radius of curvature equal to 2.037 f_A in all
four examples. The difference between the mean
refractive indices of the materials of the two elements
of such doublet component is 0.27 in all four examples.

The combined equivalent focal length of the
two simple components of the first member L_A is 4.0013 F_0
in Example I, 5.7162 F_0 in Examples II and III, and
10.0064 F_0 in Example IV or 0.8981 f_A in all four
examples. The radius of curvature R_4 of the front
surface of the first of such simple components is 2.551 f_A
in all four examples, and the radius of curvature R_6 of
the front surface of the second of such simple components
is 0.880 f_A in all four examples. The rear surface R_7
of such second simple component is convex to the front
with radius of curvature 3.852 f_A in all four examples.

The axial thickness (D_1 + D_2) of the meniscus

doublet component of the first member L_A is 0.766 F_o
in Example I, 1.094 F_o in Examples II and III, and
1.916 F_o in Example IV, or 0.172 f_A in all four
examples. The sum of the axial thicknesses of the
two simple components $(D_3 + D_4)$ of the first member
is 0.553 F_o in Example I, 0.790 F_o in Examples II and
III, and 1.383 F_o in Example IV, or 0.124 f_A in all
four examples.

The arithmetic mean between the Abbe V numbers
of the materials of the three convergent elements of
the first member L_A in all four examples is 50.72 and
thus exceeds the Abbe V number of the material of the
divergent front element by 24.62.

The maximum value of the ratio of the
equivalent focal length of the objective to the f-number
of the objective is 2.5 F_o in Example I, 3.57 F_o in
Examples II and III, and 6.25 F_o in Example IV, so that
in all four examples f_A is 1.782 times such maximum value.

In all four examples, the minimum separation
between the movable second and third members L_B and L_C
occurs when the equivalent focal length of the objective
is 7.45 F_o, and the numerical values of the equivalent
focal lengths f_B and f_C of such members are respectively
5.88 and 7.27 times the minimum value of the ratio of
the equivalent focal length of the objective to the
f-number of the objective.

The movable second member L_B in all four
examples consists of a divergent simple meniscus
component with its surfaces convex to the front followed
by a divergent triplet component having a convergent

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element between two divergent elements, and its total

axial movement (a unidirectional rearward movement) in

the range of variation is numerically equal to 1.994 f_B.

The front and rear surfaces R_8 and R_9 of the simple

meniscus component of such member respectively have radii

of curvature numerically equal to 1.89 f_B and 0.83 f_B in

all four examples, whilst the front and rear surfaces R_{10}

and R_{13} of the triplet component respectively have radii

of curvature numerically equal to 1.86 f_B in Examples

I & III and 1.87 f_B in Example IV and to 3.93 f_B in

Examples I & III and 3.99 f_B in Example IV.

The movable third member L_C in all four examples

consists of a doublet component, whose front surface R_{14}

is concave to the front with radius of curvature

numerically equal to 0.72 f_C, and the total axial

movement (the numerical sum of an initial forward

movement plus a subsequent rearward movement) of such

member is numerically equal to 0.363 f_C. The internal

contact R_{15} of such doublet component is collective and

convex to the front, with radius of curvature numerically

equal to 0.72 f_C. The difference between the mean

refractive indices of the materials of such doublet

component is 0.087 in Examples I & III and 0.088 in

Example IV, the difference between their Abbe V numbers

being 30.09 in Examples I & III and 30.24 in Example IV.

In all four examples, the various aberrations

are well stabilised in the front three members L_A, L_B, L_C

throughout the range of variation of equivalent focal

length of the objective and also throughout the focussing

range, and the stationary rear member L_D serves to balance

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out such residual stabilised aberrations, and also to locate the resultant image plane in a convenient position. The construction of such rear member may thus vary widely.

In Examples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilised aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R_{23} of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and coma with minimum effect on oblique aberrations.

In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no aspheric surface is used in the actual example given,

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some further improvement in aberration correction could
be achieved by incorporating such a surface.

Yet another alternative construction for the
stationary rear member L_D is employed in Example IV,
consisting of seven simple components, the first three
and the last two being convergent, and the fourth and
fifth divergent.   An aspheric surface is again used, in
this case the front surface R_{29} of the rearmost component.

It is often desired in practice to provide two
different ranges of variation of the equivalent focal
length of the objective, and with the objective according
to the present invention this can be carried out in a
simple way by the provision of an achromatic doublet
component, which can be placed at will behind the
stationary rear member L_D of the objective, such doublet
component, when in position, acting to move the resultant
image plane further from the rear surface of the member
L_D and to increase the values of the equivalent focal
length of the objective in the same proportion throughout
the range.   Another effect of the addition of this
doublet component is to reduce the relative aperture of
the objective and the angular field covered.   Numerical
data are given below of two alternative examples of
achromatic doublet component suited to follow the rear
member L_D of Example I above.   Figures 5 and 6
respectively show these two examples of doublet
component L_E in position behind the main objective,
which for simplicity is shown only in skeleton form,
the front and rear surfaces only being shown for each of
the four members L_A, L_B, L_C and L_D of the objective.

Example V

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter	
$R_{28} = \infty$	$S_{11} = 0.2812$			R_{28}	0.7312
$R_{29} = -2.0920$	$D_{17} = 0.0781$	1.70035	30.28	R_{29}	0.7312
$R_{30} = +3.3428$	$D_{18} = 0.0500$	1.60483	43.83	R_{30}	0.7312

Example VI

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter	
$R_{28} = \infty$	$S_{11} = 0.7369$			R_{28}	0.6749
$R_{29} = -2.0920$	$D_{17} = 0.0781$	1.70035	30.28	R_{29}	0.6749
$R_{30} = +2.0920$	$D_{18} = 0.0500$	1.60582	53.31	R_{30}	0.6749

The dimensions in these two examples of achromatic doublet component are given in terms of the minimum value F_o of the equivalent focal length for the objective of Example I. In each table S_{11} represents the air separation between the rear surface R_{27} of the stationary rear member L_D of Example I and the front surface R_{28} of the added doublet component. The doublet component in each case consists of a convergent element in front of a divergent element.

The added doublet component L_E of Example V increases the values of the equivalent focal length in the ratio 3:2, so that the normal range from F_o to 10 F_o is altered by the doublet component into a range from 1.5 F_o to 15 F_o. The doublet component of Example VI acts to double the values of the equivalent focal length of

Example I, thus giving a range from $\frac{2}{7} F_o$ to $\frac{20}{7} F_o$ when the doublet component is in position.

The back focal distance from the rear surface R_{30} of the added doublet component L_5 to the new position of the resultant image plane is $3.704 F_o$ in Example V and $4.028 F_o$ in Example VI. The relative aperture of the objective is changed from $f/4.0$ by the addition of the doublet component to $f/6.0$ in Example V and $f/8.0$ in Example VI. The semi-angular field, which for Example I alone varies from 27 degrees at F_o to 2.7 degrees at F_m, varies (when the doublet component of Example V is added) from 18 degrees at $1.5 F_o$ to 1.8 degrees at $15 F_o$, and (when the doublet component of Example VI is added) from 13.5 degrees at $2 F_o$ to 1.35 degrees at $20 F_o$.

It will be realised that the addition of only an achromatic doublet component to an already well-corrected objective must necessarily result in a lower standard of aberration correction when the doublet component is in place. But the increased equivalent focal length and reduced relative aperture and angular field do not call for so high a standard of correction as is needed when the objective is used alone, and for many practical purposes the standard of correction obtained with the doublet component added is adequate.

The necessary axial movement of the second and third members may be brought about in various ways, for example by means of two appropriately shaped cams, which may be in the form of cam grooves D and E on the inner surface of a tubular member C rotated by the zoom

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control element G and surrounding the second and third members M and H, which are held against rotation relatively to the fixed casing F of the objective. The focussing movement of the front member P may be

5   effected under the control of a focussing control element O by mounting the front member in screw threaded engagement with the fixed casing F of the objective.

It will be appreciated that the foregoing examples have been given by way of example only and that

10   the invention can be carried into practice in other ways.

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1.   An optical objective of the zoom type (that is
of the type having relatively movable members whereby
the equivalent focal length of the objective can be
continuously varied throughout a range, whilst maintaining
constant position of the image plane), corrected for
spherical and chromatic aberrations, coma, astigmatism,
field curvature and distortion, said objective having a
maximum equivalent focal length at least six times its
minimum focal length, and comprising a convergent first
member which for a given object distance remains
stationary during the zooming relative movements, an
axially movable divergent second member behind the first
member having equivalent focal length f_B lying numerically
between 4 and 8 times the minimum value of the ratio of
the equivalent focal length of the complete objective to
the f-number of the objective in the range of variation,
an axially movable divergent third member behind the
second member having equivalent focal length f_C lying
numerically between 5 and 10 times the minimum value of
such ratio, a stationary convergent fourth member behind
the third member, a zoom control element, and means
whereby operation of the zoom control element causes
the zooming relative movements to be effected, wherein
the total axial movement of the second member in the
range of variation lies numerically between $1.5f_B$ and
$2.5f_B$ and the total axial movement of the third member
in the range lies numerically between $0.25f_C$ and $0.5f_C$,
the minimum axial separation between the second and third
member occurring when the equivalent focal length of the

objective is greater than half its maximum value in the
range of variation, the movable divergent second member
consisting of a divergent simple meniscus component with
its surfaces convex to the front and a divergent compound

5   component behind such simple component, and the movable
divergent third member consisting of a doublet component
having its front surface concave to the front, ~~with radius
of curvature lying numerically between 0.5f$_B$ and 1.0f$_B$~~.

2.   An optical objective as claimed in claim 1, in

10   which the compound component in the divergent movable
second member includes at least one convergent element
and at least one divergent element made of materials
of differing
~~whose~~ Abbe V numbers ~~differ by more than 25~~.

~~3.   An optical objective as claimed in claim 2, in~~

15   ~~which the radii of curvature of the front and rear~~
~~surfaces of the simple meniscus component of the second~~
~~member respectively lie numerically between 1.5f$_B$ and~~
~~3f$_B$ and between 0.66f$_B$ and f$_B$.~~

3.   An optical objective as claimed in claim ~~3~~ in

20   which the front surface of the compound component of the
and
second member is concave to the front ~~with radius of
curvature lying numerically between 1.5f$_B$ and 3f$_B$, and~~
the rear surface of such component is convex to the front~~,
with radius of curvature lying numerically between 3f$_B$

25   and 6f$_B$~~

4.   An optical objective as claimed in claim ~~5~~, in
which the compound component of the second member consists
of a triplet component having a convergent element between
two divergent elements~~, the materials of the elements of

30   such component having mean refractive indices differing~~

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by less than 0.15 from one another, the materials of all the elements of the second member having mean refractive indices greater than 1.65 and being such that the arithmetic mean between the Abbe V numbers of the

5   materials of the divergent elements exceeds that of the convergent element by at least 25.

5.   An optical objective as claimed in claim 4, in which the doublet component constituting the third member has a collective internal contact convex to the front,

10   with radius of curvature lying numerically between $0.5f_C$ and f_C, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each greater than 1.65 and differ by between 0.05 and 0.15.

15   6.   An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front ~~with radius of curvature lying numerically between 1.5f_B and 3f_B, and~~ *and* the rear surface of such component is convex to the front.

20   ~~with radius of curvature lying numerically between 3f_B and 6f_B.~~

7.   An optical objective as claimed in claim 2, in which the doublet component constituting the third member has a collective internal contact convex to the front,

25   ~~with radius of curvature lying numerically between 0.5f_C~~ and f_C, the materials of the two elements of such component having *differing* Abbe V numbers ~~which differ by more than~~ 25 and *differing* mean refractive indices ~~which are each greater than 1.65 and differ by between 0.05 and 0.15.~~

30   8.   An optical objective as claimed in claim 1, in

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which the front surface of the compound component of the
second member is concave to the front ~~with radius of
curvature lying numerically between 1.5f_B and 2f_B and~~ *and*
the rear surface of such component is convex to the *front*.
~~front with radius of curvature lying numerically between
3f_B and 6f_B.~~

10. An optical objective as claimed in claim 9, in
which the radii of curvature of the front and rear
surfaces of the simple meniscus component of the second
member respectively lie numerically between 1.5f_B and
3f_B and between 0.66f_B and f_B.

9. An optical objective as claimed in claim 8, in
which the compound component of the second member consists
of a triplet component having a convergent element between
two divergent elements, ~~the materials of the elements of
such component having mean refractive indices differing
by less than 0.15 from one another~~ the materials of all
the elements of the second member having mean refractive
indices greater than 1.69 and being such that the
arithmetic mean between the Abbe V numbers of the
materials of the divergent elements exceeds that of the
convergent element ~~by at least 25~~.

10. An optical objective as claimed in claim 9,
including an achromatic doublet which can be placed at
will behind the stationary rear member of the objective
and acts when in its operative position to increase the
values of the equivalent focal length of the objective
by a chosen ratio throughout the range of variation.

An optical objective as claimed in claim 1, in
which the radius of curvature of the front surface of

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the simple meniscus component of the second member lies numerically between $1.5f_B$ and $3f_B$.

14. An optical objective as claimed in claim 1, in which the radius of curvature of the rear surface of the simple meniscus component of the second member lies numerically between $0.65f_B$ and f_B.

15. An optical objective as claimed in claim 1, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

16. An optical objective as claimed in claim 15, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5f_C$ and f_C, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each greater than 1.65 and differ by between 0.05 and 0.15.

17. An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5f_C$ and f_C, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25.

18. An optical objective as claimed in claim 17, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective

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and acts when in its operative position to increase the
values of the equivalent focal length of the objective
by a chosen ratio throughout the range of variation.

15. An optical objective of the zoom type (that is
of the type having relatively movable members whereby the
equivalent focal length of the objective can be
continuously varied throughout a range, whilst maintaining
constant position of the image plane), corrected for
spherical and chromatic aberrations, coma, astigmatism,
field curvature and distortion, and comprising a
convergent first member which for a given object
distance remains stationary during the zooming relative
movements, an axially movable divergent second member
behind the first member having equivalent focal length
f_B lying numerically between 4 and 8 times the minimum
value of the ratio of the equivalent focal length of the
complete objective to the f-number of the objective in
the range of variation, an axially movable divergent
third member behind the second member having equivalent
focal length f_C lying numerically between 5 and 10 times
the minimum value of such ratio, a stationary convergent
fourth member behind the third member, a zoom control
element, and means whereby operation of the zoom control
causes the zooming relative movements to be effected,
wherein the total axial movement of the second member
in the range of variation lies numerically between
$1.5f_B$ and $2.5f_B$ and the total axial movement of the
third member in the range lies numerically between
$0.25f_C$ and $0.5f_C$, the minimum axial separation between
the second and third members occurring when the

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equivalent focal length of the objective is greater
than half its maximum value in the range of variation,
the movable divergent second member consisting of a
divergent simple meniscus component with its surfaces
convex to the front and a divergent compound component
behind such simple component, the movable divergent
third member consisting of a doublet component having
its front surface concave to the front, ~~with radius of~~
~~curvature lying numerically between 0.5f_o and 1.0f_o,~~
and the first member of the objective comprises a
meniscus doublet component having a front surface which
is concave to the front and ~~has dispersive optical power~~
~~lying numerically between 0.5/f_A and 1.0/f_A (where f_A~~
~~is the equivalent focal length of the first member) and~~
two simple convergent components behind such meniscus
doublet component.

15. An optical objective as claimed in claim 15,
in which the internal contact of the meniscus doublet
component of the first member is dispersive and convex
to the front, ~~with radius of curvature between 1.5f_A and~~
~~f_A,~~ the difference between the mean refractive indices
of the materials of the two elements of the doublet
being greater than 0.15 and in which the arithmetic mean
between the Abbe V numbers of the materials of the three
convergent elements of the first member exceeds by at
least 20 the Abbe V number of the material of the
divergent front element of the meniscus doublet component
of the first member.

16. An optical objective as claimed in claim 16,
in which the compound component in the divergent movable

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second member includes at least one convergent element and at least one divergent element, ~~and the~~ *and the* ~~made of materials whose Abbe V numbers differ by more than 25, and the~~ doublet component constituting the third member has a collective internal contact convex to the front. ~~with radius of curvature lying numerically between $0.5f_C$ and f_C, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each greater than 1.65 and differ by between 0.05 and 0.15.~~

18. An optical objective as claimed in claim ~~5~~ 16, in which the two simple components of the first member together ~~have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$, and~~ have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being ~~less than $1f_A$ and~~ greater than twice the radius of curvature of the front surface of the *the rear* second of such simple components, ~~which latter radius of curvature is in turn greater than $0.75f_A$,~~ the rear surface of the second of the two simple components being convex to the front. ~~with radius of curvature between $2f_A$ and $7f_A$.~~

~~23.~~ An optical objective as claimed in claim 22, in which the radii of curvature of the front and rear surfaces of the simple meniscus component of the second member respectively lie numerically between $1.5f_B$ and $3f_B$ and between $0.66f_B$ and f_B.

19. An optical objective as claimed in claim ~~15,~~ 15 in which the axial thickness of the meniscus doublet

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component of the first member is ~~less than 0.25f~~$_A$ ~~and~~
is greater than the sum of the axial thicknesses of the
two simple components of the first member, ~~such sum in~~
~~turn~~ being greater than $0.075f_A$, the equivalent focal
length f_A of the first member lying between 1.2 and
2.4 times the maximum value of the ratio of the
equivalent focal length of the objective to the f-number
of the objective in the range of variation.

19. An optical objective as claimed in claim 19,
including an achromatic doublet which can be placed at
will behind the stationary rear member of the objective
and acts when in its operative position to increase the
values of the equivalent focal length of the objective
by a chosen ratio throughout the range of variation.

21. An optical objective as claimed in claim 15,
including an achromatic doublet which can be placed at
will behind the stationary rear member of the objective
and acts when in its operative position to increase the
values of the equivalent focal length of the objective
by a chosen ratio throughout the range of variation.

27. An optical objective as claimed in claim 26,
in which the internal contact of the meniscus doublet
component of the first member is dispersive and convex
to the front with radius of curvature between $1.5f_A$ and
$3f_A$, the difference between the mean refractive indices
of the materials of the two elements of the doublet
being greater than 0.15.

DECLARATION, PETITION AND POWER OF ATTORNEY

We, GORDON HENRY COOK and PETER ARNOLD MERIGOLD

_____ declare that we are ~~citizens of~~ both Subjects

of the Queen of England ~~respectively~~, and residents

of Oadby, County of Leicester, England; and Prestatyn, County

of Flintshire, Wales, United Kingdom,
respectively; that we have read the foregoing specification

and claims, that we verily believe ourselves to be the

original, first and joint inventors of the improvement

in OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

described and claimed in the foregoing specification; that

this application in part discloses and claims subject matter

disclosed in our earlier filed pending application Serial

No. 309,208 , filed September 16, 1963 , that as to

to subject matter of this application which is common to

said earlier application we do not know and do not believe

that the same was ever known or used before our invention

thereof or patented or described in any printed publication

in any country before our invention thereof or more than

one year prior to said earlier application, or in public

use or on sale in the United States more than one year

prior to said earlier application; that said common subject

matter has not been patented before the date of said

earlier application in any country foreign to the United

States on an application filed by us or our legal representa-

tives or assigns more than twelve months prior to said

application; and that the earliest application for patent

on said invention filed by us or our legal representatives

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or assigns in any country foreign to the United States was:

Great Britain - No. 35088 filed Sept.14,1962

that as to the subject matter of this application which
is not common to said earlier application, we do not
know and do not believe that the same was ever known or
used before our invention thereof or patented or described
in any printed publication in any country before our
invention thereof or more than one year prior to the date
of this application, or in public use or on sale in
the United States more than one year prior to the date
of this application, and that said subject matter
has not been patented in any country foreign to the
United States on an application filed by us or our legal
representatives or assigns more than twelve months prior
to the date of this application; and that no application
for patent on said invention has been filed by us or our
legal representatives or assigns in any country foreign
to the United States.

And we declare further that all statements
made herein of our own knowledge are true and that
all statements made on information and belief are
believed to be true; and further that these statements
were made with the knowledge that willful false
statements and the like so made are punishable by
fine or imprisonment, or both, under Section 1001
of Title 18 of the United States Code and that such
willful false statements may jeopardize the validity
of the application or any patent issuing thereon.

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And we hereby appoint HOLCOMBE, WETHERILL & BRISEBOIS, a firm having offices at Suite 307, Crystal Plaza Building No. 1, 2001 Jefferson Davis Highway, Arlington, Virginia 22202, Registration No. 17,348, our attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith.

Wherefore we pray that Letters Patent be granted to us for the invention or discovery described and claimed in the foregoing specification and claims, and we hereby subscribe our names to the foregoing specification and claims, declaration, power of attorney, and this petition,

(1) this ___4th___ day of ___June___, 1971.

(2) this ___2nd___ day of ___June___, 1971.

Post Office Address:

68 Stoughton Road, Oadby

Leicestershire, England

Gordon Henry Cook
Gordon   Henry   Cook

47, Meliden Road,

Prestatyn, Flints., Wales, U.K.

Peter Arnold Merigold
Peter   Arnold   Merigold
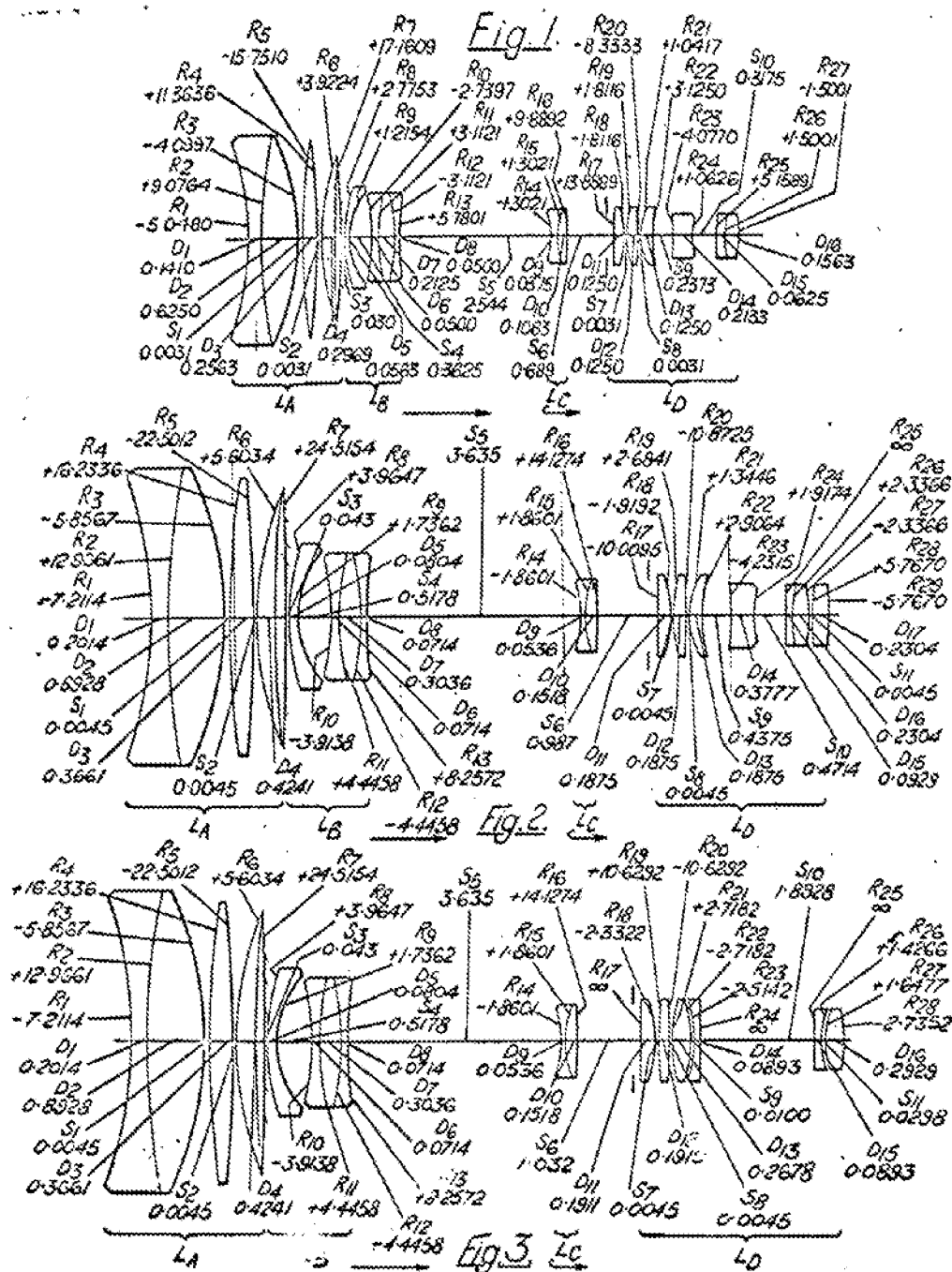
-3-

47

Fig. 1

Fig. 2

Fig. 3

Fig.4

Fig.5

Fig.6

49

Fig. 7

152254

Case Docket No. ___7955___
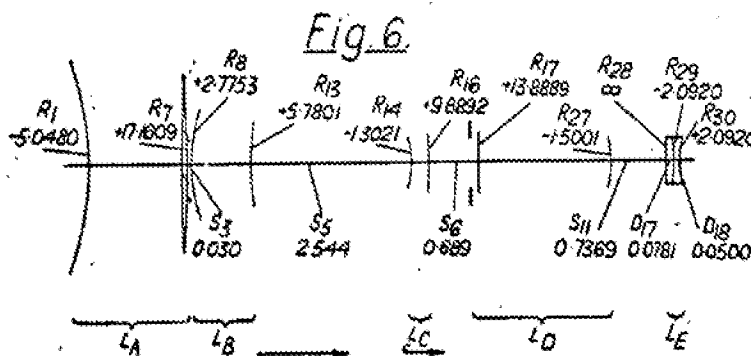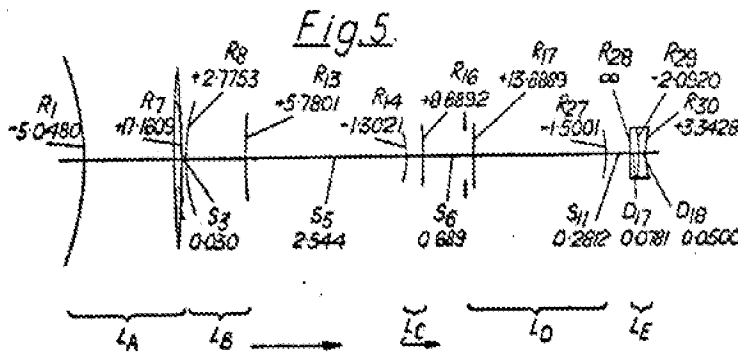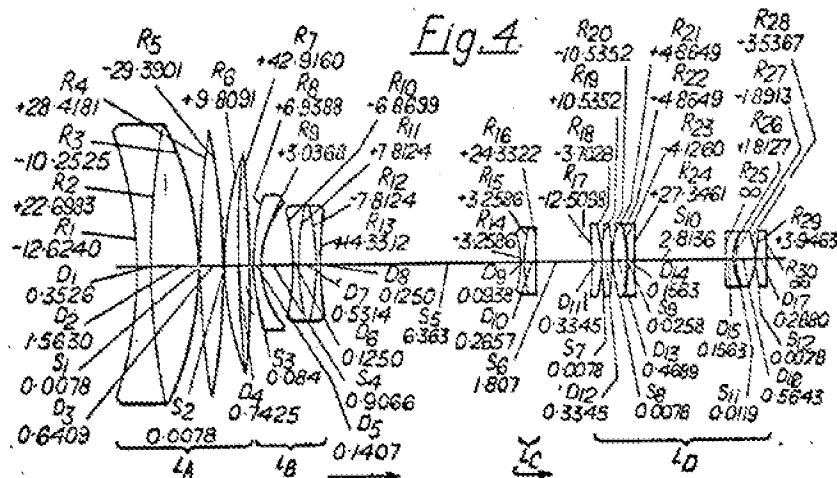
COMLE, WETHERILL & BRISEBOIS
SUITE 507, CRYSTAL PLAZA BUILDING NO. 2
JEFFERSON DAVIS HIGHWAY
ARLINGTON, VIRGINIA 22202
PHONE - (703) 521-1550

JUNE 11, 1971

THE COMMISSIONER OF PATENTS
Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the patent application of

Inventor: GORDON HENRY COOK & PETER ARNOLD MERIGOLD

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

This application is a continuation in part of SN 309,208

Enclosed are:

[X] ___3___ sheets of drawing.   2 sheets informal & 1 sheet formal

[X] An assignment of the invention to ___THE RANK ORGANISATION LIMITED___

[ ] A certified copy of a _____ application.

[ ] Associate power of attorney.

CLAIMS AS FILED				
(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) BASIC FEE $65.00
TOTAL CLAIMS	27 -10*	17	X $2.00	34.00
INDEPENDENT CLAIMS	2 -1*	1	X $10.00	10.00
				20.00 Assignment
			TOTAL FILING FEE ⟶	129.00

[ ] Please charge my Deposit Account No. _____ in the amount of $_____. A duplicate copy of this sheet is enclosed.

[X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Account No. ___08-2720___. A duplicate copy of this sheet is enclosed.

[X] A check in the amount of $ 129.00 to cover the filing fee is enclosed.

(signature)
Attorney of Record

ms

U.S. DEPARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

PLEASE REFER TO THE FOLLOWING:	GROUP ART UNIT
APPLICANT (S)	
GORDON HENRY COOK, et.al.	
SERIAL NUMBER	FILING DATE
152,254	6-11-71
OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH	

HOLCOMBE, WETHERILL & BRISEBOIS
SUITE 307
CRYSTAL PLAZA BLDG.
2001 JEFFERSON DAVIS HWY.
ARLINGTON, VIRGINIA.

NOTICE OF INSUFFICIENT FEE AND / OR INFORMAL DRAWINGS

Correction of the informality checked below is required.
APPLICANT IS GIVEN TWO (2) MONTHS WITHIN WHICH TO SUBMIT THE FORMAL DRAWINGS AND / OR FEE
to avoid abandonment of the application.

1. ☐ The filing fee of $_____submitted in this application is insufficient.

   A balance of $_____is due for additional claims.

2. ☒ The photoprints submitted in lieu of formal drawings have been accepted for filing only (Rule 85).

   Formal drawings complying with Rule 84 together with the comparison fee of $10 (or authorization to use a deposit account) are required.

   The Drafting Division of the Patent Office does not have the facilities for preparing new drawings at the present time.

To ensure prompt processing and forwarding of the formal drawings to the examiner, each sheet should include the Serial Number and Group Art Unit in the upper right margin.

MAILED
NOV 24 1971
GROUP 250

Head, Application Branch

lvw

FOR USE IN TRANSMITTING FORMAL DRAWINGS AND / OR FEE

Check the appropriate box below.

☐ Check for $_____ enclosed.

☐ Charge $_____ to my Deposit Account No._____ Two copies of this letter are enclosed.

The above is to cover the

☐ comparison fee.

☐ balance of filing fee due.

Please transmit the formal drawings and / or fee together with a copy of this form. BE SURE TO ADDRESS THE GROUP ART UNIT SHOWN ABOVE.

—51

PO 1094
REV 3/71

USCOMM-DC-50766-P71

7955

#3

IN THE UNITED STATES PATENT OFFICE

In re application of

GORDON HENRY COOK et al

Serial No. 152,254

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF
      VARIABLE EQUIVALENT
      FOCAL LENGTH

December 2, 1971

LETTER

Hon. Commissioner of Patents
Washington, D.C. 20234

Sir:

        Responsive to the enclosed letter, please transfer

from the file of the parent application, SN 309,208, filed

September 16, 1967, (now abandoned), the two sheets of drawings

in that case. These correspond to the two informal prints in-

itially filed with the above-entitled application.

                        Respectfully submitted,

                        HOLCOMBE, WETHERILL & BRISEBOIS

521-1550   By
                           Joseph F.Brisebois Reg.15,965

52

J. K. Corbin   Group 259

Paper No. _____ 4 _____

06/11/71   152-254
COOK, GORDON HENRY, ET. AL.

Mailed

HOLCOMBE, WETHERILL &
BRISEBOIS,
2001 JEFFERSON DAVIS HWY.,
SUITE 307,
ARLINGTON, VA. 22202

This is a communication from the Examiner in
charge of your application.

Commissioner of Patents

☑ This application has been examined.

☐ Responsive to communication filed_____.   ☐ This action is **made final.**

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS ACTION IS SET TO EXPIRE

_____ *Three* _____ MONTH(S) _____ DAYS FROM THE DATE OF THIS LETTER.

PART I

The following attachments(s) are part of this action:

a. ☑ Notice of References Cited, Form PO-892.   b. ☐ Notice of Informal Patent Drawing, PO-948.

c. ☐ Notice of Informal Patent Application,   d. ☐
   Form PO-152.

PART II

Summary of Action

1. ☑ Claims _____ 1-27 _____ are presented for examination.

2. ☐ Claims _____ are allowed.

3. ☐ Claims _____ would be allowable if amended as indicated.

4. ☑ Claims _____ 1-27 _____ are rejected.

5. ☐ Claims _____ are objected to.

6. ☐ Claims _____ are subject to restriction or election requirement.

7. ☐ Claims _____ are withdrawn from consideration.

8. ☐ Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 OG. 213.

9. ☐ Since it appears that a discussion with applicant's representative may result in agreements whereby the application may be placed in condition for allowance, the examiner will telephone the representative within about 2 weeks from the date of this letter.

10. ☐ Receipt is acknowledged of papers under 35 USC 119, which papers have been placed of record in the file.

11. ☐ Applicant's claim for priority based on an application filed in _____ on _____ is acknowledged. It is noted, however, that a certified copy as required by 35 USC 119 has not been received.

12. ☐ Other

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~1~

A separate letter to the Draftsman for cor-
recting the curvature of R_7 to show that it is slightly
convex to the front, as submitted in the parent case,
should be submitted in the present case.

The Yamaji, Harris et al, and Klemt et al
patents are cited to show the state of the art.

Claims 1-27 are rejected under 35 U.S.C. 112,
first paragraph, as based on a disclosure which fails to
establish the validity of the numerical ranges for cer-
tain of the lens parameters. The numerical embodiments
in the specification clearly do not support the validity
of the ranges. Further the explanation in the specifi-
cation, pages 16-20, fails to explain most of the
ranges set forth in the dependent claims. The explanation
on pages 16-20, however, does appear to establish the
truthfulness of the ranges in parent claim 1 except for
the one in the last two lines. The reasoning set forth
in In re Cook and Merigold 169 USPQ 298, and especially
as set forth on page 303 is applicable to the last
range in claim 1 and those in the dependent claims.

Allowable subject matter is consider present
in the disclosure.

J. K. Corbin:vgr
703/557/3107
5-16-72

John K. Corbin
JOHN K. CORBIN
EXAMINER
GROUP ART UNIT 259

TO SEPARATE HOLD TOP AND BOTTOM EDGES, SNAP-APART AND DISCARD CARBON

ATTACHMENT TO PAPER NO. 4

FORM PO-892 (7-69)		

NOTICE OF REFERENCES CITED

U.S. DEPARTMENT OF COMMERCE
PATENT OFFICE

SERIAL NO. 152,254   GROUP ART UNIT 259

APPLICANT(S) **Cook et al**

☐ Check here if this is a supplemental citation
(Do not prepare on additional folder)

U.S. PATENTS

	PATENT NO.	DATE	PATENTEE	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
1	3 027 805	4-1962	Yamaji	350	184	
2	3 038 378	6-1962	Harris et al (.)	350	186 X	
3	3 057 257	10-1962	Klemt et al (.)	350	184	
4						
5						
6						
7						
8						
9						
10						
11						

FOREIGN PATENTS AND SPECIFICATIONS ✳

	PATENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG.	PP. SPEC.
1								
2								
3								
4								
5								
6								

OTHER REFERENCES (Include author, title, date, pertinent pages, etc.)

EXAMINER	DATE	
John K. Corbin	5/10/72	☐ Check here if foreign exchange

✳ APPLICATIONS   56

HOLCOMBE, WETHERILL & BRISEBOIS
SUITE 307
CRYSTAL PLAZA BLDG.
2001 JEFFERSON DAVIS HWY.
ARLINGTON, VIRGINIA.

PLEASE REFER TO THE FOLLOWING:	GROUP ART UNIT
APPLICANT (S) GORDON HENRY COOK, et.al.	
SERIAL NUMBER 152,254	FILING DATE 6-11-71
OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH	

NOTICE OF INSUFFICIENT FEE AND / OR INFORMAL DRAWINGS

Correction of the informality checked below is required.
APPLICANT IS GIVEN TWO (2) MONTHS WITHIN WHICH TO SUBMIT THE FORMAL DRAWINGS AND / OR FEE to avoid abandonment of the application.

1. ☐ The filing fee of $_____submitted in this application is insufficient.

A balance of $_____is due for additional claims.

2. ☒ The photoprints submitted in lieu of formal drawings have been accepted for filing only (Rule 85).

Formal drawings complying with Rule 84 together with the comparison fee of $10 (or authorization to use a deposit account) are required.

The Drafting Division of the Patent Office does not have the facilities for preparing new drawings at the present time.

To ensure prompt processing and forwarding of the formal drawings to the examiner, each sheet should include the Serial Number and Group Art Unit in the upper right margin.

MAILED

NOV 24 1971

GROUP 250

Head, Application Branch

lvw

FOR USE IN TRANSMITTING FORMAL DRAWINGS AND / OR FEE

Check the appropriate box below.

☐ Check for $_____ enclosed.

☐ Charge $_____ to my Deposit Account No._____. Two copies of this letter are enclosed.

The above is to cover the

☐ comparison fee.

☐ balance of filing fee due.

Please transmit the formal drawings and / or fee together with a copy of this form. BE SURE TO ADDRESS THE GROUP ART UNIT SHOWN ABOVE.

53

PO 1094
REV 8/71

USCOMM DC-69786 P71

IN THE UNITED STATES PATENT OFFICE

In re application of   November 6, 1972

GORDON HENRY COOK et al

Serial No. 152,254   Gr.Art Unit 259

Filed June 11, 1971   N Edge
                                        11-13-72
For: OPTICAL OBJECTIVES OF VARIABLE
       EQUIVALENT FOCAL LENGTH   Exr. J. K. Corbin

AMENDMENT

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

    Responsive to Official Action mailed August 4, 1972,
please amend the above-entitled application as follows:

        Claim 1, next to last line, cancel "with radius" and

                substitute a period;

          cancel the last line.

        Claim 2, line 5, cancel "whose" and substitute --of

                differing--; cancel "differ by more

           than 25".

Cancel Claim 3.

        Claim 4, line 1, cancel "3" and substitute --2--;

           line 3, cancel "with radius of" and substitute

                --and--;

           cancel line 4;

           at the end of line 5 insert a period;

           cancel lines 6 and 7.

Claim 5, line 4, cancel "the materials of the elements

of" and substitute a period;

cancel lines 5-11 inclusive.

Claim 6, at the end of line 3 insert a period;

cancel lines 4-8 inclusive.

Claim 7, line 3, cancel "with radius of" and substitute

--and--;

cancel line 4;

at the end of line 5 insert a period;

cancel lines 6 and 7.

Claim 8, at the end of line 3 insert a comma;

cancel line 4;

line 5, cancel "and f_c,";

line 6, after "having" insert --differing--;

cancel "which differ by more than"'

line 7, cancel "25"; after "and" insert

--differing--; cancel "which are each

greater" and substitute a period;

cancel the last line.

Claim 9, line 3, cancel "with radius of" and substitute

--and--;

cancel line 4;

at the end of line 5 insert --front.--;

cancel lines6 and 7.

Cancel Claim 10.

Claim 11, line 4, cancel "the materials of the elements

of";

cancel line 5;

line 6, cancel "by less than 0.15 from one

another";

Claim 11, line 8, cancel "1.65" and substitute --1.69--;

last line, cancel "by at least 25".

Cancel Claims 13 and 14.

Rewrite Claims 16 and 17 as follows:

--16/12 (Amended) An optical objective as claimed in Claim 15, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature [lying numerically between 0.5f_C and f_C] substantially equal to 0.72f_C, the materials of the two elements of such component having Abbe V numbers which differ by [more than 25] about 30 and mean refractive indices which are each greater than [1.65] 1.69 and differ by [between 0.05 and 0.15] about 0.09.

17. 13 (Amended) An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature [lying numerically between 0.5f_C and f_C] substantially equal to 0.72f_C, the difference between the mean refractive indices of the materials of the two elements of such component [lying between 0.05 and 0.15] being about 0.09,[whilst] while the difference between the Abbe V numbers of such materials [exceeds 25] is about 30.

Claim 19, line 35, cancel "with radius of" and sub-
stitute a comma;

cancel line 36;

line 39, cancel "has dispersive optical
power";

cancel lines 40 and 41.

-3-

59

Claim 20, cancel line 4, and substitute --to the front.--;

cancel lines 5-12 inclusive.

Claim 21, line 4, cancel "made of materials" and sub-

stitute --, and the--;

cancel line 5;

line 7, cancel "with" and substitute a period;

cancel lines 8-12 inclusive.

Claim 22, cancel line 3 and substitute --together--;

line 4, cancel "between $0.75f_A$ and $1.25f_A$,

and";

line 7, cancel "less than $4f_A$ and";

line 9, cancel "which latter radius" and

substitute --the rear--;

cancel line 10;

line 12, cancel "with radius of curvature"

and substitute a period;

cancel the last line.

Cancel Claim 23.

Claim 24, line 3, cancel "less than $0.25f_A$ and";

line 5, cancel ", such sum in" and substitute

a period;

cancel lines 6-10 inclusive.

Rewrite Claim 27 as follows:

--27 22 (Amended) An optical objective as claimed in

claim 26, in which the internal contact of the meniscus doublet

component of the first member is dispersive and convex to the

front with radius of curvature [between $1.5f_A$ and $3f_A$] substan-

tially equal to $2.04f_A$, the difference between the mean refractive

indices of the materials of the two elements of the doublet being

[greater than 0.15] substantially 0.27.--

a^2

-4-   60

REMARKS

The criticized range in the last two lines of Claim 1 has been eliminated, since the approximate curvature of the front surface of the third member may be deduced by a skilled lens designer to lie within this range, once he has been given the basic information contained earlier in the claim.

The dependent claims have likewise been amended to eliminate unsubstantiated ranges.

The required letter to the Official Draftsman is attached hereto.

Since none of the references were applied to the claims, the application is now presumed to be in condition for allowance.

Respectfully submitted,

GORDON HENRY COOK et al

By _____
Joseph F. Brisebois Reg.15,965
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
JFB:gw

-5-

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IN THE UNITED STATES PATENT OFFICE

In re application of   November 6, 1972

GORDON HENRY COOK et al

Serial No. 152,254   Gr.Art Unit 259

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE
     EQUIVALENT FOCAL LENGTH   Exr. J. K. Corbin

LETTER TO OFFICIAL DRAFTSMAN

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

        Please correct the surface R_7 in each of Figures 1-6

to show it as slightly convex to the front, as indicated in red

on the attached prints, and charge the cost of this work to our

Miscellaneous Account No. 08-2720, Order No. 53.

                        Respectfully submitted,

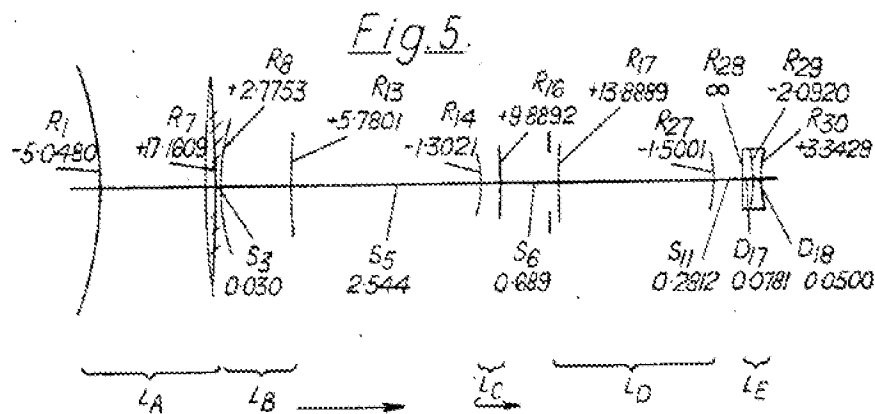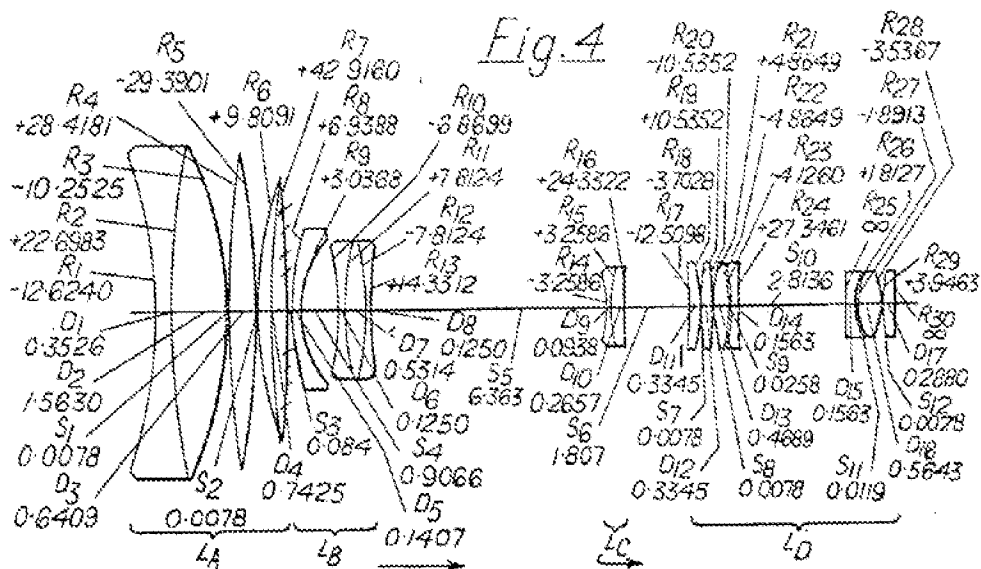   GORDON HENRY COOK et al

521-1550
JFB:gw   By _____
                   Joseph P. Brisebois Reg.15,965
                   HOLCOMBE, WETHERILL & BRISEBOIS

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Fig. 1.

Fig. 2. Ic

Fig. 3. Ic

Fig.4

Fig.5.

Fig.6.

n. Edge
11-21-72

Paper No. ___7/6___
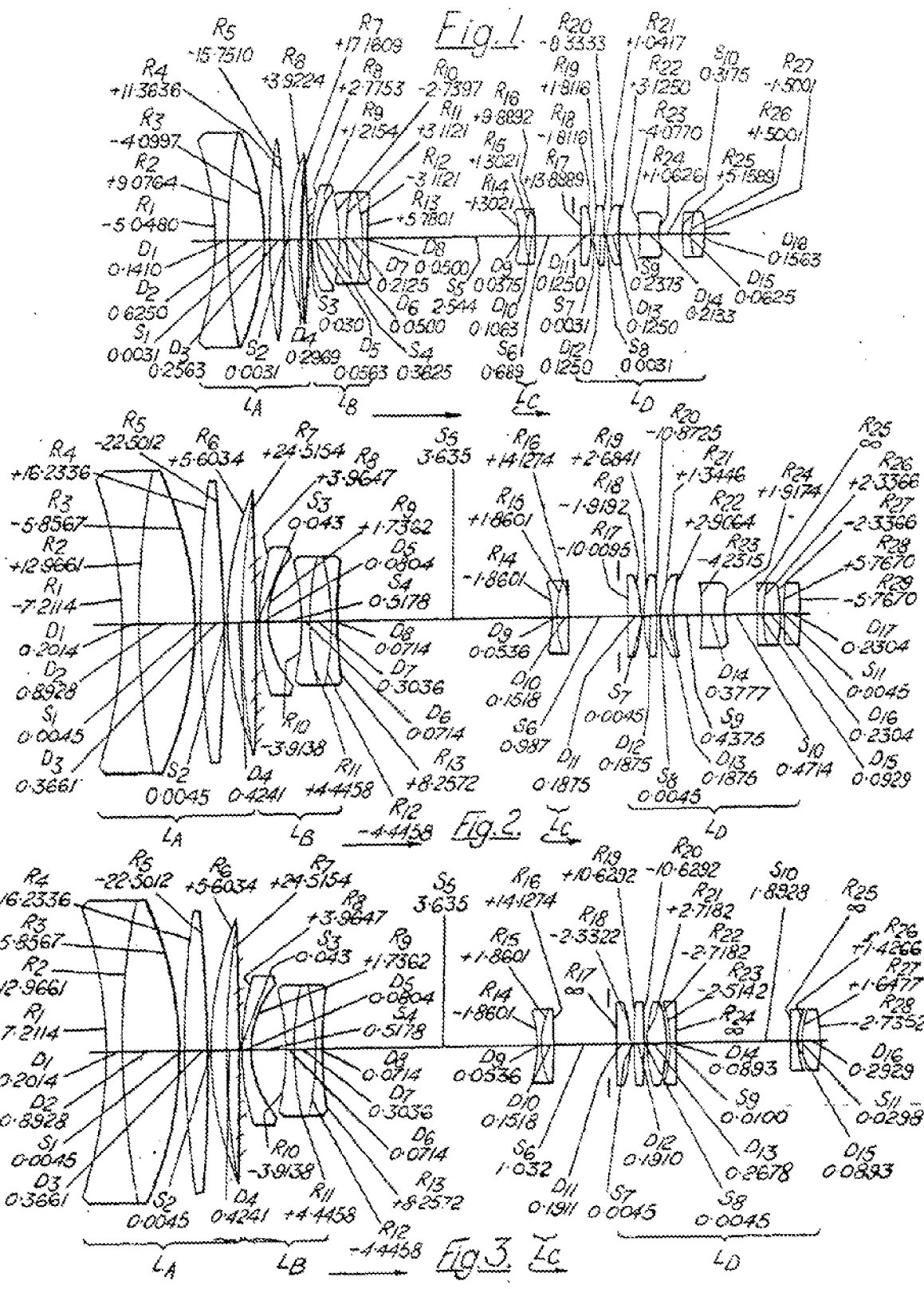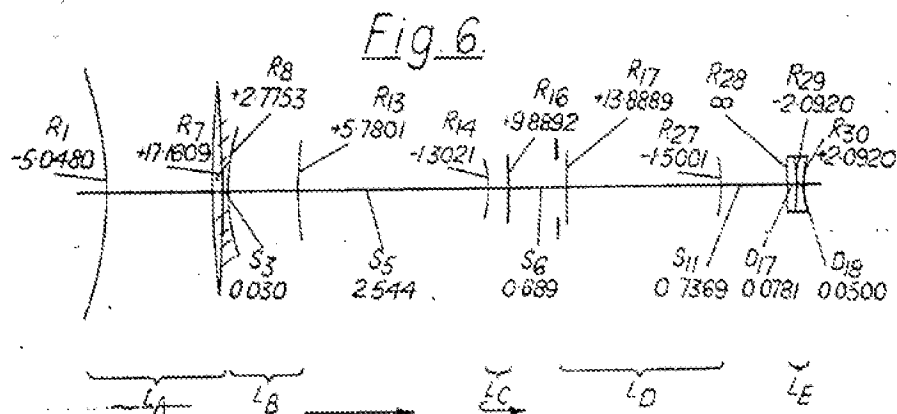
In Reply Please Refer To The Following:

EXAMINER'S NAME	J. K. Corbin	
259	June 11, 1971	152,254
GR. ART UN.	FILING DATE	SERIAL NO.

Mailed _____

Gordon Henry Cook et al

APPLICANT	INVENTION

OPTICAL OBJECTIVES OF VARIABLE
EQUIVALENT FOCAL LENGTH

DEC 20 1972

GROUP 250

Holcombe, Wetherill, & Brisebois
2001 Jefferson Davis Hwy., Suite 307
Arlington, Va. 22202

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents

CHANGES AND/OR ADDITIONS TO THE APPLICATION RECORD MADE BY THE EXAMINER UPON ALLOWANCE

This application is in condition for allowance and the following changes have been made therein by the Examiner. Should the changes be unacceptable to applicant, an appropriate amendment may be proposed *after the Notice of Allowance has been received, as provided under Rule 312.* To ensure consideration of such an amendment, it must be submitted on or before remittance of the Base Issue Fee.

PROSECUTION ON THE MERITS IS CLOSED. A NOTICE OF ALLOWANCE WILL BE MAILED IN DUE COURSE.

[ ] Note attached Notice of References Cited, PO-892, which is part of this communication. The listed references are considered to be pertinent to the claimed invention, but the claims are deemed patentable thereover.

In line 8 of page 3 ---, now abandoned----been inserted after "1963".

J. K. Corbin:sas

703/557/3107

11-17-72

John K. Corbin

JOHN K. CORBIN
EXAMINER
GROUP ART UNIT 259

POL-85
(REV. 10.70)

U.S. DEPARTMENT OF COMMERCE
Patent Office

NOTICE OF ALLOWANCE
AND BASE ISSUE FEE DUE

The application identified below has been examined and found allowable for issuance of Letters Patent.

	FILING DATE	SERIAL NO.	NO. OF CLAIMS ALLOWED	EXAMINER AND GROUP ART UNIT
	06/11/71	152254	22	Corbin 259
APPLICANT(S)	Cook, Gordon Henry; England, and Merigold, Peter Arnold; Wales			MAILED Jan. 10, 1973 mlb
TITLE OF INVENTION (X indicates as amended by examiner)	Optical objectives of variable equivalent focal length			

BASE FEE COMPUTATION				BASE FEE DUE	CLASS-SUB
$100.00	+ $6 (FOR DWG. @ $2 PER SHEET)	+ $10 (FOR FIRST PAGE PRINTED SPEC.)		$116	350/186.000

The complete Issue Fee is one hundred dollars ($100) plus two dollars ($2) for each sheet of drawing, plus ten dollars ($10) for each printed page of specification (including claims) or portion thereof.

Inasmuch as the final number of printed pages cannot be determined in advance of printing, an initial BASE ISSUE FEE (consisting of the fee for printing the first page of specification ($10) plus the fee of ($2) for each sheet of drawing, added to the fee of $100) _must be paid within three months from the date of this notice,_ or the application shall be regarded as ABANDONED.

When remitting said Base Issue Fee, enclosed Form POL-85b should be used, and if use of a Deposit Account is being authorized, POL-85c should also be forwarded.

The Base Issue Fee will not be accepted from anyone other than the applicant, his assignee, attorney, or a party in interest as shown by the records of the Patent Office.

If an assignment has not been previously filed and it is desired to have the patent issue to the assignee, the assignment must be received in this Office with the recording fee together with the Base Issue Fee. In any event, the appropriate space(s) under "Assignment Date" on POL-85b must be completed. Where there is an assignment, the assignee's address must be given to ensure its inclusion in the printed patent.

In connection with the address of the inventor(s), attention is directed to Form POL-231 enclosed.

A Notice of Balance of Issue Fee Due will be mailed together with the patentee's copy of the patent _if an additional fee is due._ Payment must be made within three months from the date shown on said Notice since FAILURE TO PAY THIS BALANCE WITHIN THE TIME SPECIFIED WILL RESULT IN LAPSE OF THE PATENT.

Holcombe, Wetherill, et al
2001 Jefferson Davis Hwy.,
Suite 307
Arlington, Va. 22202

IMPORTANT

ATTENTION IS DIRECTED TO RULE 334
REVISED NOVEMBER 4, 1969.

THE PATENT WILL ISSUE TO APPLICANT
UNLESS AN ASSIGNEE IS SHOWN IN
ITEM 2 ON FORM POL-85b. ATTACHED

PATENT OFFICE COPY

66

BEST COPY

MAR - 9 1973 -24   100 — 10 — 6 —

U.S. Department of Commerce
Patent Office

BASE ISSUE FEE TRANSMITTAL

KEYED

MAIL ROOM MAR 9 1973

This form is provided in lieu of formal transmittal and should be used for transmitting the Base Issue Fee. Items numbered 1 through 4 below should be completed as appropriate. The Base Issue Fee Receipt will be mailed to the address appearing in item 4 or as designated in item 4a below.

1. The COMMISSIONER OF PATENTS is requested to apply the Base Issue Fee to the application identified below and deliver the patent to:

March 9, 1973
(DATE)

Holcombe Wetherill Basebar
(SIGNATURE OF PARTY IN INTEREST OF RECORD)

PRIORITY DOCUMENTS ATTACHED

NOTE: The Base Issue Fee will not be accepted from anyone other than the applicant, his assignee, or attorney, or a party in interest as shown by the records of the Patent Office, nor will this fee be accepted in the application prior to the Notice of Allowance.

FILING DATE	SERIAL NO.	NO. OF CLAIMS ALLOWED	EXAMINER AND GROUP ART UNIT
06/11/71	152254	22	Corbin 259

APPLICANT(S): Cook, Gordon Henry; England, and Marigold, Peter Arnold; Wales

MAILED Jan. 10, 1973 mlb

TITLE OF INVENTION (X indicates as amended by examiner): Optical objectives of variable equivalent focal length

NOTICE OF ALLOWANCE DATE

BASE FEE COMPUTATION				BASE FEE DUE	CLASS-SUB
$100.00	÷ 86 (FOR DWG @ $2 PER SHEET)	+ $10	(FOR FIRST PAGE PRINTED SPEC.)	$116	350/186,000

2. ASSIGNMENT DATA (print or type)

A. The appropriate box(es) in this item MUST be checked:

(1) This application is NOT assigned;
(2) xx This application IS assigned;
(3) Assignment herewith;
(4) xx Assignment recorded and returned by Patent Office:
   xx YES   ☐ NO

B. For printing on the patent: (Unless an assignee is identified below, the patent will issue to the applicant above-named. Completion of this item, however, is NOT a substitute for filing the assignment as required in Rule 334)

(1) NAME OF ASSIGNEE:
   THE RANK ORGANISATION LIMITED

(2) ADDRESS: (City & State or Country)
   London, England

(3) STATE OF INCORPORATION, IF ASSIGNEE IS A CORPORATION: England

2. BASE FEE ENCLOSED:
   ☒ YES   ☐ NO

Charge to my Deposit Account Number: _____
(POL-85c must be enclosed)

a. ☐ For Base Fee
b. ☐ For Balance of Issue Fee Due, if any.
c. ☐ For Recording Enclosed Assignment

03/15/73	152254	106 2	100.00	CK
03/15/73	152254	107 2	10.00	CK
03/15/73	152254	108 2	6.00	CK

DO NOT USE THIS SPACE

MAILING INSTRUCTIONS

NOTE: All further correspondence, the patent together with the Notice of Balance of Issue Fee Due, if any, will be mailed to the addressee entered in the stub marked 4 at the lower left below, unless you direct otherwise by specifying the appropriate name and address in item 4a below right.

4a. Further correspondence is to be mailed to the following:

93

MAR
9
1973

IN THE UNITED STATES PATENT OFFICE

In re application of   March 9, 1973

GORDON HENRY COOK et al   Alld. Jan.10,1973

Serial No. 152,254   Final Fee Pd. Mar.9,1973

Filed June 11, 1971   Gr. Art Unit 259

For: OPTICAL OBJECTIVES OF VARIABLE
      EQUIVALENT FOCAL LENGTH   Exmr. Corbin

CLAIM OF PRIORITY

Honorable Commissioner of Patents
Washington, D.C.   20231

Sir:

        Applicants hereby claim the priority of their corres-

ponding British application No. 35088 filed in Great Britain,

September 14, 1962 by applicants' assignee RANK PRECISION

INDUSTRIES LIMITED trading as THE RANK ORGANISATION RANK TAYLOR

HORSON DIVISION as is permitted by British law, applicants being

the true and first inventors.

        A certified copy of said British application is

attached.

        Please note that this application is a continuation-

in-part of application Serial No. 309,208, filed

September 16, 1963.

                            Respectfully submitted,

                            GORDON HENRY COOK et al

                            By _____
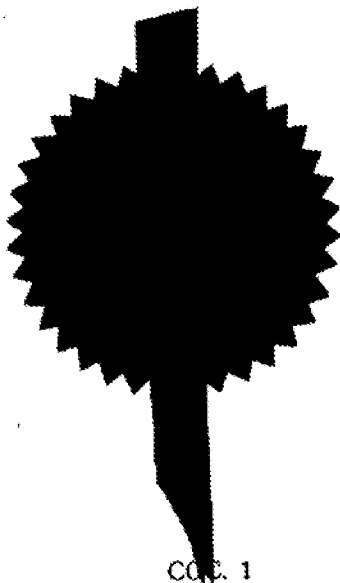   Joseph F. Brisebois Reg.No. 15,965
                            HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
dkf   67

THE PATENT OFFICE,
25 SOUTHAMPTON BUILDINGS,
LONDON.

I, the undersigned, being an officer duly authorised in accordance with Section 62(3) of the Patents and Designs Act, 1907, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of documents as originally filed in connection with the Patent application identified therein.
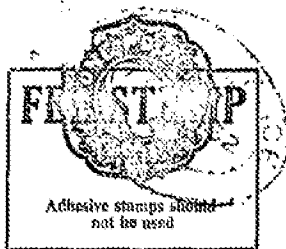
WITNESS my hand this 9 day of February 1973

CC. 1

6266 D.185353 40M 1/71 T.P. Gp.658

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Patents Form No. 1

No. 35088
1962
VI

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PATENTS ACT, 1949

APPLICATION FOR PATENT

(To be accompanied by two copies of Patents Form No. 2
or of Patent Form No. 3)

Note: This is a comprehensive form and parts inappropriate to a particular application should be cancelled. In the case of an application by the inventor, only parts 1, 4 and 6 of this form are appropriate, together with part 5 if a Patent of Addition is applied for.

(a) Insert (in full) name, address and nationality of applicant(s).

1. I/We (a) BAIRD PRECISION INDUSTRIES LIMITED trading

as THE BAIRD ORGANISATION BAIRD PARTON MORSOL DIVISION,

a British Company, of 104, Stoughton Street, Leicester

(b) Delete the words which are not applicable.

(c) Insert title of invention.

am/are in possession of an invention which is described in the accompanying (b) ~~provisional~~ complete specification under the title (c) IMPROVEMENTS

"IN OR RELATING TO OPTICAL GEOMETRIES OR VARIABLE
"EQUIPMENT TOTAL LUTION".

(d) Insert name of inventor if included at (a)

(b) (I
(We
(The said (d)
~~claim~~ to be the ~~true and first inventor~~ of the invention.

or

(e) Insert (in full) name, address and nationality of inventor(s) if not included at (a)

2. I/We believe (e) Gordon Henry COOK, British Subject,

of 68, Stoughton Road, Oadby, in the County of

Leicester, and Peter Arnold MERIGOLD, British Subject,
of "Ribblesdale", 49, Gedgefield Drive, Thurnby, in
the County of Leicester,
to be the true and first inventor s of the invention.

and (b) (I
(we
(the said BAIRD PRECISION INDUSTRIES LIMITED trading
as THE BAIRD ORGANISATION BAIRD PARTON MORSOL DIVISION
(am
(b) (are the (b)
(is
(assignee of the said inventor in respect of the right to
(make this application.
(personal representative of the said inventor

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P.T.O.

(f) Insert (in full) name and address and nationality of communicator.

by (f) ....

Use of the invention in the United Kingdom before the date of the application for a patent is, in general, a lawful ground of objection.

4. I/We declare that to the best of my/our knowledge and belief the statements made above are correct and there is no lawful ground of objection to the grant of a patent to me/us on this application and I/we pray that a patent may be granted to me/us for the said invention.

5. And I/We request that the patent may be granted as a PATENT OF ADDITION to

(b) (patent No. ....
    (the patent to be granted on application No. ....

6. And I/We request that all notices, requisitions, and communications relating to this application may be sent to ..... A. P. PHILLIPS,

(g) The address must be in the United Kingdom.

at (g) Chancery House, 53/64, Chancery Lane, London, W.C.2.

....

(h) Delete if not applicable.

(h) who is/are hereby appointed to act for me/us.

FOR AND ON BEHALF OF
RANK PRECISION INDUSTRIES LTD.

(i) To be signed by applicant(s).

(i) ....
                                    SECRETARY

Declaration to be signed by anyone named as inventor in part 2 who is not an applicant. I/We assent to the making of this application.

The Comptroller,
    The Patent Office, 25 Southampton Buildings,
        Chancery Lane, London, W.C.2.

NOTICE TO INVENTORS

Attention of applicants is drawn to the desirability of avoiding publication of inventions relating to any article, material or device intended or adapted for use in war (Official Secrets Acts 1911 and 1920).

In such cases, after an application for a patent has been filed at the Patent Office, the Comptroller will consider whether publication or communication of the invention should be prohibited or restricted under Section 18 of the Act and will inform the applicant if such prohibition is necessary. Applicants are reminded that, under the provision of this Section, applications may not be filed abroad without written permit or unless an application has been filed not less than six weeks previously in the United Kingdom for a patent for the same invention and no direction prohibiting publication or communication has been given.

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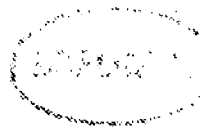
PATENTS ACT 1949.

14 SEPT 1952

FORM 2.   35088
1962

PROVISIONAL SPECIFICATION.

"IMPROVEMENTS IN OR RELATING TO OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH".

We, RANK PRECISION INDUSTRIES LIMITED trading as
THE RANK ORGANISATION RANK TAYLOR HOBSON DIVISION, a British
Company, of 104, Stoughton Street, Leicester, do hereby
declare this invention to be described in the following
statement:-

1.

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This invention relates to an optical objective of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane, whereby the size of the image can be varied. Accommodation for change of object position is usually achieved by imparting an additional movement to the front member of the objective.

Many difficulties arise in the design of such objectives, and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this usually involve the use of relatively complicated movable members in the objective in order to make it possible in such movable members to stabilise the aberrations throughout the range of variation, such stabilised aberrations then being compensated in a stationary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the zoom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity

of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions or have introduced too severe optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the zooming movements for varying the equivalent focal length, so that this member is concerned only with focussing movements and is relieved of the complication of superimposing focussing movements on zooming movements. Such an arrangement is utilised in the present invention, wherein the primary object is to provide an improved arrangement of the movable system of the objective, which can be employed with various different arrangements of the front member and will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

The optical objective of the zoom type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative movements, the second and third are divergent and movable, and the fourth is convergent and stationary, the position of minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths f_B and f_C respectively of the movable second and third members lie respectively between 4 and 5

times the minimum value of the ratio of the equivalent focal
length of the objective to the f/number of the objective in
the range of variation and between 5 and 10 times such minimum
ratio, the divergent movable second member consisting of a
divergent simple meniscus component with its surfaces convex
to the front followed by a divergent compound component and
performing during the range of variation a total axial move-
ment lying between $1.5f_B$ and $2.5f_B$, whilst the divergent mov-
able third member consists of a doublet component having a
front surface concave to the front with radius of curvature
between $0.5f_C$ and $1.0f_C$ and performs during the range of
variation a total axial movement lying between $0.25f_C$ and $0.5f_C$

It is to be understood that the terms "front" and "rear",
as used herein, relate respectively to the sides of the ob-
jective nearer to and further from the longer conjugate in
accordance with the usual convention.

It should also be made clear that the term "internal
"contact", when used in connection with a compound component,
is intended to include, not only a cemented contact, but also
what is commonly known as a "broken contact", that is one in
which the two contacting surfaces have slightly different
radii of curvature, the effective radius of curvature of
such a broken contact being the arithmetic mean between the
radii of curvature of the individual contacting surfaces,
whilst the optical power of the broken contact is the harmonic
mean between the optical powers of the individual contacting
surfaces.

The characteristics of the movable second and third
members above specified contribute towards keeping the overall

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dimensions of the objective as small as possible and achieving the best compromise between the diameters and the relative apertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures of the individual members, and at the same time to assist towards the desired stabilisation of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbé V numbers differ from one another by more than 15, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilisation of astigmatism and distortion, the radius of curvature of the front surface of the simple meniscus component of the second member preferably lies between $1.5f_B$ and $3f_B$, and further assistance towards stabilisation of astigmatism can be obtained by arranging for the radius of curvature of the rear surface of such component to lie between $0.66f_B$ and $1.0f_B$.

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature between $1.5f_B$ and $3f_B$, the rear surface of such component being convex to the front with radius of curvature

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between $3f_2$ and $6f_2$, thus assisting towards stabilisation of spherical aberration and coma.

Whilst such compound component may consist of a doublet component, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials for the various elements, facilitates correction of chromatic aberration and the desired stabilisation of the other aberrations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one another by more than 0.15. The arithmetic mean between the Abbé V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature between $0.5f_2$ and f_2, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbé V numbers of such materials exceeds 25. These features contribute towards the desired

stabilisation of spherical aberration and coma and also
facilitate individual correction of the third member for
chromatic aberration.

As in the case of the second member, it is preferable to
employ materials for the elements of the third member having
mean refractive indices greater than 1.65, in order to avoid
excessive surface curvatures and thus facilitate the attain-
ment of a wide relative aperture for the member.

A movable system arranged in the manner above described
in accordance with the present invention is suitable for use
with various different arrangements of the first member of
the objective, but it is especially advantageous for such
member to have one or more of the following characteristics:-

A) The first member is preferably convergent and may com-
prise a front meniscus doublet component with its front and
rear surfaces concave to the front followed by two simple
convergent components, the front surface of the doublet com-
ponent having dispersive optical power lying numerically be-
tween $0.5/f_A$ and $1.0/f_A$, where f_A is the equivalent focal
length of the first member. These features permit the rear
nodal point of the first member to be far to the rear and
preferably behind the rear surface of the member, for coopera-
tion with the forwardly located front nodal point of the
second member.

B) The internal contact of the meniscus doublet component
of the first member may be dispersive and convex to the front
with radius of curvature between $1.5f_A$ and $3f_A$, the differ-
ence between the mean refractive indices of the materials
of the two elements of such doublet component being greater

than 0.15. These features contribute towards stabilisation of spherical aberration and astigmatism over the desired focussing range to suit different object distances.

C) The two simple components of the first member may together have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4f_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than $0.75f_A$. These features assist towards stabilising the aberrations, especially spherical aberration and astigmatism, not only throughout the range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D) The rear surface of the rear component of the first member may be convex to the front with radius of curvature between $2f_A$ and $7f_A$. This feature contributes towards stabilisation of primary astigmatism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E) The axial thickness of the meniscus doublet component of the first member may be less than $0.25f_A$ and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than $0.075f_A$. These features contribute towards the desired rearward location of the rear nodal point of the first member.

F) The arithmetic mean between the Abbé V numbers of

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the materials of the three convergent elements of the first member may exceed by at least 20 the Abbé V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G) The equivalent focal length f_A of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f/number of the objective. This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

Various combinations of the foregoing features may be incorporated in the arrangement of the first member, and it is especially advantageous to arrange such member in accordance with the invention forming the subject of the present applicants' British Patent Application No.35053 of 1962, filed concurrently herewith. The objective in accordance with the invention of such concurrent patent application has four members of which the first for a given object distance remains stationary during the zooming relative movements, the second and third members are movable, and the fourth is stationary, at least one of the movable second and third members being divergent, whilst the first member is convergent and comprises a front meniscus doublet component followed by two simple convergent components, such doublet component having a front surface concave to the front with dispersive optical power lying numerically between $0.5/f_A$ and $1.0/f_A$ and an internal contact which is dispersive and convex to the front with radius of curvature between $1.5f_A$ and $3f_A$, the difference

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between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15, whilst the two simple components of the first member together have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$ and have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4f_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature is in turn greater than $0.75f_A$.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the objective to be stationary and to be located behind the movable third member of the objective.

Numerical data for some convenient practical examples of zoom objective according to the present invention are given in the following tables, in which R_1, R_2.....designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, D_1, D_2..... designate the axial thicknesses of the individual elements of the objective, and S_1, S_2...... designate the axial air separations between the components of the objective. The tables also give the mean refractive indices n_d for the d-line of the spectrum and the Abbé V numbers of the materials from which the various elements of the objective are made, and in addition the clear diameters of the various surfaces of the objective.

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The second section of each table gives the values of
the three variable axial air separations between the four
members of the objective for a number of representative posi-
tions, for which the corresponding values of the equivalent
focal length F of the complete objective from its minimum
value F_0 to its maximum value F_m are also given, together
with the corresponding values of log F.

Some of the tables also have a third section giving the
equation defining an axial section through an aspheric surface
provided in the stationary rear member of the objective, the
radius of curvature given for such surface in the first sec-
tion of the table being the radius of curvature at the vertex
of the surface.

The dimensions in each table are given in terms of F_0.

Example 1.

Radius		Thickness or Air Separation		Refractive Index n_d	Abbé V Number	Clear Diameter	
R_1	− 5.0480					R_1	3.4435
		D_1	0.1410	1.7847	26.10		
R_2	+ 9.0764					R_2	3.4750
		D_2	0.6250	1.51507	56.35		
R_3	− 4.0997					R_3	3.4870
		S_1	0.0031				
R_4	+ 11.3636					R_4	3.3715
		D_3	0.2563	1.717	47.90		
R_5	− 15.7510					R_5	3.3610
		S_2	0.0031				
R_6	+ 3.9224					R_6	3.1035
		D_4	0.2969	1.717	47.90		
R_7	+ 17.1609					R_7	3.0707
		S_3	variable				
R_8	+ 2.7753					R_8	1.7000
		D_5	0.0563	1.69734	56.10		
R_9	+ 1.2154					R_9	1.4812
		S_4	0.3625				
R_{10}	− 2.7397					R_{10}	1.4712
		D_6	0.0500	1.69734	56.39		
R_{11}	+ 3.1121					R_{11}	1.4092
		D_7	0.2125	1.7847	26.10		
R_{12}	− 3.1121					R_{12}	1.3947
		D_8	0.0500	1.69734	56.10		
R_{13}	+ 5.7301					R_{13}	1.3412
		S_5	variable				
R_{14}	− 1.3021					R_{14}	0.7807
		D_9	0.0375	1.69734	56.19		
R_{15}	+ 1.3021					R_{15}	0.8205
		D_{10}	0.1063	1.7847	26.10		
R_{16}	+ 9.8892					R_{16}	0.8300
		S_6	variable				
R_{17}	+ 13.5889					R_{17}	0.8865
		D_{11}	0.1250	1.524	58.57		
R_{18}	− 1.8116					R_{18}	0.9017
		S_7	0.0031				
R_{19}	+ 1.8116					R_{19}	0.9157
		D_{12}	0.1250	1.524	58.87		
R_{20}	− 8.3333					R_{20}	0.9102
		S_8	0.0031				
R_{21}	+ 1.0417					R_{21}	0.8858
		D_{13}	0.1250	1.524	58.87		
R_{22}	+ 3.1250					R_{22}	0.8602
		S_9	0.2375 (aspheric)				
R_{23}	− 4.0770					R_{23}	0.7560
		D_{14}	0.2133	1.7283	28.66		
R_{24}	+ 1.0826					R_{24}	0.6907
		S_{10}	0.3175				
R_{25}	+ 5.1589					R_{25}	0.7197
		D_{15}	0.0625	1.7283	28.66		
R_{26}	+ 1.5001					R_{26}	0.7200
		D_{16}	0.1563	1.61492	56.22		
R_{27}	− 1.5001					R_{27}	0.7225

S_3	S_5	S_6	P	$\log P$
0.03023	2.54423	0.68058	1.00000	0.00
1.11409	1.40738	0.74157	1.77827	0.25
1.93430	0.60333	0.72521	3.16227	0.50
2.55076	0.16104	0.55123	5.62939	0.75
2.96233	0.16657	0.13414	10.00000	1.00

Equation for aspheric surface R_{23}

$$z = -4.077 + \sqrt{16.62193 - x^2} - 0.02459203\, x^4 + 0.08809172\, x^6$$
$$- 0.2440590\, x^8 - 0.07842450\, x^{10}$$

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Example II.

Radius	Thickness or Air Separation		Refractive Index n_d	Abbé V Number	Clear Diameter	
R_1 − 7.2114	D_1	0.2014	1.7847	26.10	R_1	4.9192
R_2 + 12.9661	D_2	0.8928	1.51507	56.35	R_2	4.9642
R_3 − 5.8567	S_1	0.0045			R_3	4.9814
R_4 + 16.2336	D_3	0.3661	1.7170	47.90	R_4	4.8164
R_5 − 22.5012	S_2	0.0045			R_5	4.8014
R_6 + 5.6034	D_4	0.4241	1.7170	47.90	R_6	4.4335
R_7 + 24.5154	S_3	variable			R_7	4.3867
R_8 + 3.9647	D_5	0.0804	1.69734	56.19	R_8	2.4286
R_9 + 1.7362	S_4	0.5178			R_9	2.1161
R_{10} − 3.9173	D_6	0.0714	1.69734	56.19	R_{10}	2.1018
R_{11} + 4.4458	D_7	0.3036	1.7847	26.10	R_{11}	2.0132
R_{12} − 4.4458	D_8	0.0714	1.69734	56.19	R_{12}	1.9925
R_{13} + 8.2572	S_5	variable			R_{13}	1.9161
R_{14} − 1.8601	D_9	0.0536	1.69734	56.19	R_{14}	1.1153
R_{15} + 1.8601	D_{10}	0.1518	1.7847	26.10	R_{15}	1.1721
R_{16} + 14.1274	S_6	variable			R_{16}	1.1857
R_{17} − 10.0095	D_{11}	0.1875	1.5168	64.20	R_{17}	1.2552
R_{18} − 1.9192	S_7	0.0045			R_{18}	1.2861
R_{19} + 2.6541	D_{12}	0.1875	1.5168	64.20	R_{19}	1.3110
R_{20} − 10.8725	S_8	0.0045			R_{20}	1.3033
R_{21} + 1.3446	D_{13}	0.1875	1.5168	64.20	R_{21}	1.2672
R_{22} + 2.9064	S_9	0.4375 (aspheric)			R_{22}	1.2220
R_{23} − 4.2315	D_{14}	0.3777	1.7283	28.66	R_{23}	1.0506
R_{24} + 1.9174	S_{10}	0.4714			R_{24}	0.9686
R_{25} ∞	D_{15}	0.0929	1.7283	28.66	R_{25}	1.0019
R_{26} + 2.3366	D_{16}	0.2304	1.61342	59.27	R_{26}	1.0088
R_{27} − 2.3366	S_{11}	0.0045			R_{27}	1.0186
R_{28} + 5.7670	D_{17}	0.2304	1.61342	59.27	R_{28}	1.0068
R_{29} − 5.7670					R_{29}	0.9770

S_3	S_5	S_6	F	$\log F$
0.04318	3.63462	0.98730	1.00000	0.00
1.59156	2.01054	1.06300	1.77827	0.25
2.76329	0.86219	1.03962	3.16227	0.50
3.64395	0.23005	0.75109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

Equation for aspheric surface R_{23}

$$x = -4.2315 + \sqrt{17.90539 - x^2} - 0.01663305\, y^4 + 0.02010143\, y^6$$
$$- 0.00178346\, y^8 - 0.03953320\, y^{10}$$

15. RS

Example III.

Radius			Thickness or Air Separation		Refractive Index n_d	Abbé V Number	Clear Diameter	
R_1	−	7.2114	D_1	0.2014	1.7847	26.10	R_1	4.9192
R_2	+	12.9661	D_2	0.8928	1.51507	56.35	R_2	4.9642
R_3	−	5.8567	S_1	0.0045			R_3	4.9014
R_4	+	16.2336	D_3	0.3661	1.7170	47.90	R_4	4.8164
R_5	−	22.5012	S_2	0.0045			R_5	4.8014
R_6	+	5.6034	D_4	0.4241	1.7170	47.90	R_6	4.4335
R_7	+	24.5154	S_3	variable			R_7	4.3867
R_8	+	3.9647	D_5	0.0804	1.69734	56.19	R_8	2.4286
R_9	+	1.7362	S_4	0.5178			R_9	2.1161
R_{10}	−	3.9138	D_6	0.0714	1.69734	56.19	R_{10}	2.1018
R_{11}	+	4.4458	D_7	0.3036	1.7847	26.10	R_{11}	2.0132
R_{12}	−	4.4458	D_8	0.0714	1.69734	56.19	R_{12}	1.9925
R_{13}	+	8.2572	S_5	variable			R_{13}	1.9161
R_{14}	−	1.8601	D_9	0.0536	1.69734	56.19	R_{14}	1.1193
R_{15}	+	1.8601	D_{10}	0.1518	1.7847	26.10	R_{15}	1.1721
R_{16}	+	14.1274	S_6	variable			R_{16}	1.1857
R_{17}		∞	D_{11}	0.1911	1.524	58.87	R_{17}	1.2830
R_{18}	−	2.3322	S_7	0.0045			R_{18}	1.3098
R_{19}	+	10.6292	D_{12}	0.1910	1.524	58.87	R_{19}	1.3238
R_{20}	−	10.6292	S_8	0.0045			R_{20}	1.3283
R_{21}	+	2.7812	D_{13}	0.2678	1.61342	59.27	R_{21}	1.3273
R_{22}	−	2.7812	S_9	0.0100			R_{22}	1.3060
R_{23}	−	2.5142	D_{14}	0.0893	1.72830	28.66	R_{23}	1.3049
R_{24}		∞	S_{10}	1.8928			R_{24}	1.2833
R_{25}		∞	D_{15}	0.0893	1.72830	28.66	R_{25}	0.9600
R_{26}	+	1.4266	S_{11}	0.0298			R_{26}	0.9600
R_{27}	+	1.6477	D_{16}	0.2929	1.69734	56.19	R_{27}	0.9600
R_{28}	−	2.7352					R_{28}	0.9600

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S_4	S_5	S_6	F	$\log F$
	5.63462	1.0319	1.00000	0.00
1.59156	2.01054	1.1076	1.77827	0.25
2.76329	0.86219	1.03422	3.16227	0.50
3.64395	0.23005	0.83569	5.62939	0.75
4.23190	0.23796	0.23984	10.00000	1.00

In all these examples, the maximum value F_E of the equivalent focal length F of the objective is ten times the minimum value F_0 thereof. Example I is corrected for a relative aperture f/4.0, whilst Examples II and III are each corrected for a relative aperture f/2.8. Examples II and III differ from one another solely in the stationary rear member, the front three members being identical in the two examples. Such front three members are in fact similar to the front three members of Example I, the dimensions being scaled up from those of Example I in the ratio of the f/numbers, that is in the ratio 4.0/2.8. The rear members in Examples II and III are, however, not scaled-up versions of the rear member of Example I. All three examples cover a semi-angular field of view varying from 27 degrees at F_0 to 3 degrees at F_E.

The iris diaphragm in all three examples is stationary and is located between the movable third member and the stationary fourth member. In Example I the diaphragm is 0.0625 F_0 in front of the surface R_{17} and has diameter 0.6568 F_0, whilst in Example II the diaphragm is 0.0929 F_0 in front of the surface R_{17} and has diameter 1.2240 F_0, and in Example III it is 0.1379 F_0 in front of the surface R_{17} and has diameter 1.224 F_0.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F_0 in Example I, 2.6761 F_0 in Example II and 2.3027 F_0 in Example III.

All three examples incorporate the invention of the concurrent British Patent Application above mentioned.

The equivalent focal length f_A of the stationary first member is + 4.4551 F_0 in Example I and + 6.3644 F_0 in Examples II and III; the equivalent focal length f_B of the movable second member is − 1.4703 F_0 in Example I and − 2.1004 F_0 in Examples II and III; the equivalent focal length f_C of the movable third member is − 1.8176 F_0 in Example I and − 2.5966 F_0 in Examples II and III; and the equivalent focal length f_D of the stationary fourth member is + 1.4753 F_0 in Example I, + 2.1286 F_0 in Example II and + 2.3232 F_0 in Example III; the positive and negative signs respectively indicating convergence and divergence.

In all three examples, the convergent stationary front member consists of a meniscus doublet component followed by two convergent simple components. The front surface R_1 of the doublet component is concave to the front and has dispersive optical power numerically equal to $0.1554/F_0$ or $0.6924/f_A$ in Example I, $0.1088/F_0$ or $0.6924/f_A$ in Examples II and III. The internal contact R_2 of the doublet component is dispersive and convex to the front and has radius of curvature equal to $2.0373 f_A$ in all three examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is .27 in all three examples.

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The combined equivalent focal length of the two simple components of the first member is 4.0013 F_O or 0.8981 f_A in Example I, 5.7162 F_O or 0.8981 f_A in Examples II and III. The radius of curvature R_4 of the front surface of the first of such simple components is 2.5907 f_A in all three examples, whilst the radius of curvature R_6 of the front surface of the other simple component is 0.8504 f_A in all three examples.

The rear surface R_7 of the rear component of the first member is convex to the front and has radius of curvature equal to 3.8520 f_A in all three examples.

The axial thickness $(D_1 + D_2)$ of the meniscus doublet component of the first member is 0.7660 F_O or 0.1719 f_A in Example I and 1.0942 F_O or 0.1719 f_A in Examples II and III. The sum of the axial thicknesses $(D_3 + D_4)$ of the two simple components of the first member is 0.5532 F_O or 0.1242 f_A in Example I and 0.7902 F_O or 0.1242 f_A in Examples II and III.

The arithmetic mean between the Abbé V numbers of the materials of the three convergent elements of the first member in all three examples is 50.72 and thus exceeds the Abbé V number of the divergent front element of the first member by 24.62.

In Example I the maximum value of the ratio of the equivalent focal length of the objective to the f/number of the objective is 2.5 F_O, so that f_A is 1.7620 times such maximum value, whilst in Examples II and III such maximum ratio is 3.571 F_O, so that f_A is again 1.7620 times such maximum ratio.

The position of minimum separation between the movable second and third members occurs when the equivalent focal

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length of the objective is 7.45 F_0 in all three examples. The equivalent focal lengths f_B and f_0 respectively of the second and third members are respectively 5.8812 and 7.2704 times the minimum value of the ratio of the equivalent focal length of the objective to the f/number of the objective in all three examples.

The movable second member in all three examples consists of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent element between two divergent elements, and its total axial movement in the range of variation is numerically equal to 1.9942 f_B.

The front and rear surfaces R_8 and R_9 of the simple meniscus component of the second member respectively have radii of curvature numerically equal to 1.8876 f_B and 0.9266 f_B. The front and rear surfaces R_{10} and R_{13} of the triplet component of such member respectively have radii of curvature numerically equal to 1.8634 f_B and 3.9312 f_B.

The movable third member in all three examples consists of a doublet component whose front surface R_{14} is concave to the front with radius of curvature numerically equal to 0.7164 f_0, and the total axial movement of such member is numerically equal to 0.3050 f_0.

The internal contact R_{15} of the doublet component of the third member is collective and convex to the front and has radius of curvature numerically equal to 0.7164 f_0. The difference between the mean refractive indices of the materials of the two elements of such doublet component is .0874 and the difference between their Abbé V numbers is 30.09.

In all three examples, the various aberrations are well stabilised in the front three members throughout the range of variation of equivalent focal length of the objective and also throughout the focusing range, and the stationary rear member serves to balance out such residual stabilised aberrations, and also to locate the resultant image plane in a convenient position. The construction of such member may thus vary widely. In Examples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a single divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilised aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R_{23} of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and coma with minimum effect on oblique aberrations. In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no aspheric surface is used in the

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actual example given, some further improvement in aberration correction could be achieved by incorporating such a surface.

It will be appreciated that, although it is preferred to employ a front member arranged in accordance with the invention of the concurrent British patent application above mentioned, this is by no means essential to the invention and other arrangements of the front member may also be advantageously used in cooperation with the movable system above described.

A. F. Pillinger

AGENT FOR THE APPLICANTS.

U.S. DEPARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

·March 22, 1973

Holcombe, Wetherill & Brisebois
2001 Jefferson Davis Hwy.
Suite 307
Arlington, Va. 22202

In re Gordon H. Cook, et al
Serial No. 152,254
Filed June 11, 1971
For: Optical Objectives of
Variable Equivalent Focal Length

Gentlemen:

Receipt is acknowledged of papers filed on March 9, 1973

purporting to comply with the requirements of Title 35, U.S. Code, Sec. 119 (1952), and

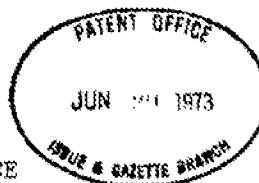they have been placed of record in the file.

Issue Control Officer
Issue and Gazette Division

POL-147 (9-70)   USCOMM-DC 60207-P71

7955

mrs Shelton

IN THE UNITED STATES PATENT OFFICE

GORDON HENRY COOK et al   June 28, 1973

Serial No. 152,254

Filed: June 11, 1971

For: OPTICAL OBJECTIVES OF   U.S. Patent No. 3,736,048
      VARIABLE EQUIVALENT
      FOCAL LENGTH

Exmr. Corbin

Group Art Unit 259   Granted: May 29, 1973

REQUEST FOR CERTIFICATE OF CORRECTION
UNDER RULE 322

Honorable Commissioner of Patents   NOV 1973
Washington, D.C. 20231

Sir:

     It is respectfully requested that the Official Letters
Patent, above-identified, be corrected as per attached sheet.

     Please correct the spelling of the assignee's name
to read THE RANK ORGANISATION LIMITED.

     The necessary claim of priority and certified copy
were filed in the Patent Office on March 9, 1973, however this
information was omitted from the heading of the Letters Patent.

     Please note that these were clerical errors in the
printing of the patent.

                              Respectfully submitted,

APPROVED   GORDON HENRY COOK et al

OCT 12 1973

R.C. Meen   By *[signature]*
FOR THE COMMISSIONER OF PATENTS   Joseph F. Brisebois Reg.No. 15,965
                              HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
df   95

IN THE UNITED STATES PATENT OFFICE

In re application of

GORDON HENRY COOK et al

JUL 25 1973

Patent No. 3,736,048

Granted: May 29, 1973

For: OPTICAL OBJECTIVES OF
VARIABLE EQUIVALENT
FOCAL LENGTH

Request for Certificate
of Correction filed
June 28, 1973

NOTICE OF CHANGE OF ATTORNEY'S
FIRM NAME AND ADDRESS

Hon. Commissioner of Patents
Washington, D. C. 20231

Sir:

This will advise that as of August 1, 1973, the

firm name and address of the undersigned attorneys of

record in the above case will be:

BRISEBOIS & KRUGER
Suite 612
2361 Jefferson Davis Highway
Arlington, Virginia 22202

Respectfully submitted,

HOLCOMBE, WETHERILL & BRISEBOIS

By _____

Joseph F. Brisebois - Reg. 15,965

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IN THE UNITED STATES PATENT OFFICE

In re application of   November 6, 1972

GORDON HENRY COOK et al

Serial No. 152,254   Gr.Art Unit 259

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE
     EQUIVALENT FOCAL LENGTH   Exr. J. K. Corbin

LETTER TO OFFICIAL DRAFTSMAN

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

Please correct the surface R_7 in each of Figures 1-6 to show it as slightly convex to the front, as indicated in red on the attached prints, and charge the cost of this work to our Miscellaneous Account No. 08-2720, Order No. 53.

Respectfully submitted,

GORDON HENRY COOK et al

521-1550   By _____
JFB:gw   Joseph F. Brisebois Reg.15,965
                               HOLCOMBE, WETHERILL & BRISEBOIS

Line	Code	Serial Number	Filing Date	Status	Patent Number	Patent Date
104	72	309,209	9/16	03		
105						
106						
107						
108						
109						
110						
111						
112						
113						
114						
115						
116						
117						

CONDITION AND STATUS CODES FOR CONTINUING DATA

CODE	CONDITION
01	Now Patented
03	Now Abandoned
71	A continuation of (including streamline)
81	which is a continuation of
72	A continuation-in-part of
82	which is a continuation-in-part of
75	and a continuation-in-part
73	A substitute for
74	A division of
84	which is a division of
86	; said
90	and
91	and a continuation of
92	, each

NOTE: When the codes 86 and 92 are used they must be followed by a code in the series 80 (81, 82, or 84); the conditions beginning with "which is....".

MPI Family Report (Family Bibliographic and Legal Status)

In the MPI Family report, all publication stages are collapsed into a single record, based on identical application data. The bibliographic information displayed in the collapsed record is taken from the latest publication.

Report Created Date: 2009-11-24

Name of Report:

Number of Families: 1

Comments:

Table of Contents

Family1

1 records in the family.

US3736048A   19730529

[no drawing available]

(ENG) OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Assignee: RANK ORGANISATION LTD

Inventor(s): COOK G H   ; MERIGOLD P A

Application No: US 3736048D A

Filing Date: 19710611

Issue/Publication Date: 19730529

Abstract: (ENG) A zoom lens having an improved zooming range and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length fb lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length fC lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5fB and 2.5fB and the total axial movement of the third member in the range lies numerically between 0.25fC and 0.5fC, the minimum axial separation between the second and third members occurring when the equivalent focal length of the object is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between 0.5fC and 1.0fC.

Priority Data: US 15225471 19710611 A 1;

Related Application(s):   04/309208 19630916   US   ABANDONED

IPC (International Class):   G02B01517

ECLA (European Class):   G02B01517

US Class: 359683; 359688; 359708

Publication Language: ENG

Filing Language: ENG

Agent(s):   Holcombe, Wetherill & Brisebois

Examiner Primary: Corbin, John K.

Assignments Reported to USPTO:
Reel/Frame: 04864/0110 **Date Signed:** 19871021 **Date Recorded:** 19880502
Assignee: RANK TAYLOR HOBSON LIMITED, 2 NEW STAR ROAD, LEICESTER, LE4 7JQ, UNITED KINGDOM A CORP. OF UNITED KINGDOM

Assignor: RANK ORGANISATION PLC, THE.

Corres. Addr: LERNER, DAVID, LITTENBERG KRUMHOLZ & MENTLIK 600 SOUTH AVENUE
WEST WESTFIELD, NEW JERSEY 07090

Brief: ASSIGNMENT OF ASSIGNORS INTEREST.

Legal Status:

Date	+/-	Code	Description
19880502	()	AS	New owner name: RANK TAYLOR HOBSON LIMITED, 2 NEW STAR ROAD, LEICE; : ASSIGNMENT OF ASSIGNORS INTEREST.;ASSIGNOR:RANK ORGANISATION PLC, THE,;REEL/FRAME:004864/0110; Effective date: 19871021;